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Comprehensive Review for the NAVLE®

Patricia A. Schenck



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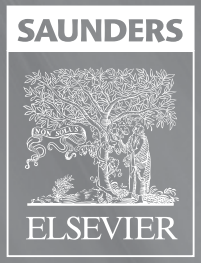
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Comprehensive Review for the NAVLE®

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Preface

Saunders Comprehensive Review for the NAVLE® is the first and only review text for the NAVLE® (North American Licensing Examination). Passing the NAVLE® is a requirement for licensure to practice veterinary medicine in North America, and approximately 10% of students who take the NAVLE® do not pass it. This comprehensive text, in outline format for ease of review, will help students prepare for the NAVLE® by covering the content on each of the major disciplines on which the NAVLE® questions are based. The companion CD-ROM bound inside the book provides additional examination preparation by allowing students to practice their test-taking skills in one of two ways: answering questions only from the areas they need to study most, or to taking a mock 360-question NAVLE® examination. The content review of the essential topics in veterinary medicine in the text and the pool of 1,600 practice questions available on the companion CD combine to make *Saunders Comprehensive Review for the NAVLE®* an invaluable study tool for any veterinary medicine student.

REVIEW BOOK

The book contains 59 chapters and is organized into five sections: General Disciplines in Veterinary Medicine, Small Animal, Equine, Food Animal, and Exotics. Topics covered in those sections include hematology, dermatology, pharmacology, surgery, preventive medicine, and important diseases and disorders. The division of the text by species and the outline format of the content facilitate the student's review process. Writers are recognized authorities in their fields, and much of the content is cultivated from Elsevier's leading veterinary texts.

COMPANION CD-ROM

The CD bound inside each book contains 1,600 quiz questions in study mode and a 360-question practice exam that can be taken in exam mode.

Challenging review questions have been created to correlate with each chapter of the review book. Answers are accompanied by rationales for increased comprehension. To further emulate the licensing examination, certain questions include images that the test taker must consider to be able to answer each question.

PRACTICE QUIZ (STUDY MODE)

The study mode includes a pool of 1600 multiple-choice questions that can be randomized so that the student can use any number of questions an unlimited number of times. The student may also choose to use questions from only the specific chapters he or she most needs to study. The student receives instant feedback as to whether the question was answered correctly or incorrectly. If the student answers correctly the rationale is provided; if the student answers incorrectly the correct answer with rationale is provided.

EXAM MODE

Exam mode is built to emulate the NAVLE® test-taking experience. The exam contains 360 NAVLE®-style questions, and the examination is scored; once it is completed or once time runs out, the student can review the exam in its entirety with answers, rationales, and references to relevant chapters. Rationales are provided for correct answer choices. This feature allows students to determine why their answers are correct or incorrect so that they are able to determine which content areas require further study. In review mode, a bar graph displays all of the sections of the exam, showing students which sections require further study. Results of the student's performance may be archived for comparison with results of exams taken later.

Some of the questions on the CD use the case-based format with relevant radiographs, photos, and patient histories that students will use to formulate their answers. Answers are provided for every question, and rationales are provided for every correct answer so that students can evaluate how well they have learned the material before they take the real board examination.

Software Updates Feature

The companion CD has a software updating system embedded. This system includes an online update capability to allow the user to download future updates or to read messages from the publisher. The CD includes an option: "Select the *Check for Updates* button to periodically check for updates or messages for this software. If updates are available, the software will step you through the download and installation process. You must be connected to the internet for this feature to work."

INTERACTIVE EXAM PRACTICE CD-ROM

A separate interactive exam practice CD is also available for sale. It offers more than 6,400 review questions and has a built-in scoring function that allows you to

monitor your progress. The test taker can review questions two ways:

- *Review by specific topic or species:* Practice questions offer students the ability to take a nearly unlimited number of tests, answering as many or as few questions as they want at one time. Case-based questions offer students the opportunity to apply concepts learned in their studies to real-life situations, like they will be required to do when they take the NAVLE®, Feedback is immediate and includes rationales for correct answers.
- *Sample test in blocks of 60 questions with a time limit of 65 minutes:* This ratio of the number of questions to the length of time emulates the actual NAVLE® test-taking experience.

STUDY TIPS

- When you are reading *Saunders Comprehensive Review for the NAVLE®,* highlight topics that you feel you need require additional study.
- When you take a quiz on the companion CD, select questions from the chapters where you have highlighted the most topics. After you feel comfortable with your knowledge of that material, try to take a 360-question practice test through Exam Mode on the CD-ROM. When you view your results from the practice test, note the sections where you missed the most questions. Go back and review those sections in the book, then take questions on the CD from only that section through Study Mode. Try taking a practice test again through Exam Mode and see how your results improve.
- When you take practice tests, take them in a quiet environment and make sure you are not interrupted. This will help you prepare best for the board examination experience and will give you the most accurate results for your practice tests. Strong preparation can help decrease test-day anxiety.
- It is important to take care of yourself during this crucial time. Be sure to sleep well, eat a balanced diet, and maintain a routine that includes scheduled blocks of study time to prohibit procrastination.

— Patricia A. Schenck

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—Patricia A. Schenck

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Contents

SECTION I GENERAL DISCIPLINES IN VETERINARY MEDICINE

Chapter 1 Clinical Pathology: Clinical Chemistry, 1
Chapter 2 Clinical Pathology: Cytology, 18
Chapter 3 Clinical Pathology: Hematology, 24
Chapter 4 Dentistry, 31
Chapter 5 Diagnostic Imaging, 40
Chapter 6 Food Safety, 56
Chapter 7 Necropsy Techniques, 65
Chapter 8 Ophthalmology, 84
Chapter 9 Pharmacology, 94
Chapter 10 Toxicology, 111

SECTION II SMALL ANIMAL

Chapter 11 Anesthesia, 155
Chapter 12 Cardiovascular Disorders, 165
Chapter 13 Dermatology, 189
Chapter 14 Emergency Medicine, 201
Chapter 15 Endocrine Disorders, 208
Chapter 16 Gastrointestinal Disorders, 225
Chapter 17 Hematology, 249
Chapter 18 Infectious Diseases, 260
Chapter 19 Nervous System Disorders, 277
Chapter 20 Nutrition, 290
Chapter 21 Oncology, 297
Chapter 22 Orthopedic Disorders, 305
Chapter 23 Preventive Medicine, 332
Chapter 24 Reproductive Disorders, 342
Chapter 25 Respiratory Disorders, 353
Chapter 26 Restraint, 365
Chapter 27 Soft Tissue Surgery, 368
Chapter 28 Urinary System Disorders, 384

SECTION III EQUINE

Chapter 29 Anesthesia, 401
Chapter 30 Behavior, 407
Chapter 31 Cardiovascular Disease, 410
Chapter 32 Hematology, 414
Chapter 33 Dermatology, 419
Chapter 34 Diagnostic Imaging, 425
Chapter 35 Endocrine Disorders, 429
Chapter 36 Gastrointestinal Diseases, 435
Chapter 37 Infectious Diseases, 439
Chapter 38 Nervous System Disorders, 447
Chapter 39 Nutrition, 456
Chapter 40 Oncology, 459
Chapter 41 Ophthalmology, 465
Chapter 42 Orthopedic Disorders, 467
Chapter 43 Preventive Medicine, 470
Chapter 44 Reproductive Disorders, 475
Chapter 45 Respiratory Disorders, 485
Chapter 46 Restraint, 493
Chapter 47 Surgery, 495
Chapter 48 Urinary Disorders, 539

SECTION IV FOOD ANIMAL

Chapter 49 Bovine Medicine and Management, 543
Chapter 50 Camelid Medicine and Management, 570
Chapter 51 Ovine/Caprine Medicine and Management, 577
Chapter 52 Swine Medicine and Management, 592
Chapter 53 Poultry Medicine and Management, 599

SECTION V EXOTICS

Chapter 54 Pet Birds, 611
Chapter 55 Ferrets, 625
Chapter 56 Rabbits, 629
Chapter 57 Rodents, 636
Chapter 58 Reptiles, 642
Chapter 59 Zoo Animals, 648
Index 671

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Clinical Pathology: Clinical Chemistry

CHAPTER 1

Patricia A. Schenck

EVALUATION OF RENAL FUNCTION

I. Blood urea nitrogen (BUN)
 A. Decreased glomerular filtration rate (GFR) results in increased BUN
 B. Affected by urea production in the liver and the rate of excretion by the kidney
 C. Increased dietary protein and gastrointestinal (GI) bleeding both increase BUN

II. Creatinine
 A. An elevation indicates that less than 25% of the original functioning renal mass remains
 B. A normal serum creatinine concentration does not exclude the possibility of renal disease
 C. Young animals have lower serum creatinine concentrations than do older animals
 D. Cachexia often causes lower serum creatinine concentrations

III. Serum phosphorus concentration
 A. An increase in serum phosphorus is not seen until more than 85% of nephrons are nonfunctional in chronic renal diseases
 B. Tubular reabsorption of phosphorus is regulated by parathyroid hormone. Renal secondary hyperparathyroidism tends to keep the serum phosphorus concentration within normal limits by excreting more phosphorus into the urine until renal disease is advanced
 C. Serum phosphorus concentrations can be much higher in immature animals because of bone growth

IV. Renal clearance (estimation of GFR)
 A. Endogenous creatinine clearance determination
 1. Collect all urine for 12 or 24 hours (record volume), and determine serum and urine creatinine concentrations
 2. Performed when renal disease is suspected but both BUN and serum creatinine concentrations are normal
 B. Exogenous creatinine clearance
 1. Creatinine is administered subcutaneously or intravenously (IV); then urine is collected via catheterization three times at 20-minute intervals
 2. Better method than endogenous creatinine clearance and approximate inulin clearance in dogs
 C. Single-injection methods for estimation of GFR
 1. Post-iohexol clearance
 a. Give iohexol IV, and collect plasma at 2, 3, and 4 hours postiohexol
 b. Plasma clearance is calculated using the area under the plasma concentration vs. time curve
 2. Inulin clearance is considered the gold standard for measurement of GFR, but inulin is not easily measured and is not available at commercial laboratories

V. Urine osmolality
 A. There is usually a linear relationship between urine osmolality and specific gravity
 B. Urine osmolality depends on the number of osmotically active particles present in urine
 C. If urine contains a large amount of larger-molecular-weight solutes such as glucose, mannitol, or radiographic contrast agents, the urinary specific gravity will be disproportionately high compared with the osmolality

VI. Fractional excretion of electrolytes
 A. Sodium
 1. Useful in the differentiation of prerenal and primary renal azotemia
 2. In animals with prerenal azotemia and volume depletion, there should be sodium conservation with a very low fractional excretion of sodium
 3. In animals with primary renal disease, the fractional excretion of sodium should be higher than normal
 B. Potassium
 1. May be useful in the evaluation of chronic renal failure patients with hypokalemia to determine whether the kidneys are contributing to the hypokalemia
 2. Varies considerably depending on diet
 C. Phosphorus
 1. May be useful during treatment of chronic renal failure to determine whether dietary or drug therapy is effective with a reduction in fractional excretion of phosphorus

2. Does not offer any advantage in diagnosis of chronic renal failure

VII. Urinary enzymes
- A. γ-glutamyltransferase (GGT) is a membrane-bound enzyme specific for renal tubular damage
- B. *N*-acetyl-β-D-glucosaminidase (NAG)
 1. Lysosomal enzyme produced by many tissues but not filtered normally
 2. Increases in urinary NAG are specific for renal tubular damage

VIII. Urinalysis
- A. Physical properties
 1. Color
 a. Normally colorless to deep amber in color (if very concentrated). Deep amber color may also be due to bile pigments
 b. Red or reddish brown color is due to intact red blood cells (RBCs), hemoglobin, or myoglobin
 c. Dark brown to black is most likely due to the conversion of hemoglobin to methemoglobin
 d. Yellow-brown to yellow-green is due to bilirubin
 e. Green color may be due to *Pseudomonas* infection or to oxidation of bilirubin to biliverdin
 2. Appearance
 a. Urine is normally clear in dogs but may be cloudy in about 20%
 b. Cloudy urine usually contains increased cells, crystals, mucus, or casts
 c. Horse urine is typically cloudy because of mucus
 d. Rabbit urine is white and opaque because of the high concentration of calcium carbonate
 3. Odor
 a. The normal odor of urine is due to volatile fatty acids
 b. An ammonia odor is due to release of ammonia by urease-producing bacteria
 4. Urine specific gravity (USG) is the weight of urine compared to that of distilled water
 a. USG estimated by dipstrip is NOT accurate. USG should be estimated by refractometry. Make sure the refractometer is temperature compensated and has different scales for different species
 b. First-morning urine samples typically have the highest urinary concentration
 c. Dogs or cats with any detectable dehydration should elaborate maximally concentrated urine (USG >1.040)
- B. Chemical examination
 1. pH
 a. Measurement by pH meter is superior to dipstrip methods
 b. Urine pH varies with diet and acid-base balance. Urine pH is usually acidic in carnivores and alkaline in herbivores
 c. Causes of acidic urine include meat diets, administration of acidifying agents, metabolic acidosis, respiratory acidosis, or paradoxical aciduria in metabolic alkalosis with potassium and chloride depletion
 d. Causes of alkaline urine include plant-based diets, urine that has been allowed to stand open to air at room temperature, postprandial alkaline tide, urinary tract infection (UTI) by urease-positive organisms, contamination of sample with bacteria during or after collection, administration of alkalinizing agents, metabolic alkalosis, respiratory alkalosis, stress induction of respiratory alkalosis (cats), and distal renal tubular acidosis
 2. Protein
 a. Trace to 1+ protein is normal in urine with high USG
 b. Dipstick methods are more sensitive to albumin than globulins
 c. False positives occur in very alkaline urine or in urine contaminated with benzylalkonium chloride
 d. Renal proteinuria may result from increased glomerular filtration of protein, failure of tubular reabsorption of protein, tubular secretion of protein, protein leakage from damaged tubular cells, or renal parenchymal inflammation
 e. Persistent moderate or heavy proteinuria in the absence of urine sediment abnormalities suggests glomerular disease
 f. Active sediment with mild to moderate proteinuria suggests inflammatory renal disease or lower urinary tract disease
 3. Glucose
 a. Normally not present in dog and cat urine
 b. Glucose appears in urine if plasma glucose exceeds approximately 180 mg/dL in the dog and 300 mg/dL in the cat
 c. Causes of glucosuria include diabetes mellitus (most common), stress or excitement (especially in cats), chronically sick cats in the absence of hyperglycemia, renal tubular disease, administration of glucose-containing fluids, and severe urethral obstruction in some cats
 4. Ketones
 a. Not normally present in dog and cat urine
 b. Inadequate consumption of carbohydrates or impaired utilization of carbohydrates can lead to ketone production
 c. Causes of ketonuria include diabetic ketoacidosis (most common), starvation or prolonged fasting, glycogen storage disease, low carbohydrate-high fat diet, and persistent hypoglycemia (decreased insulin induces ketone formation)
 5. Bilirubin
 a. Only conjugated bilirubin appears in the urine. A small amount of bilirubin may normally be seen in concentrated urine samples from normal male dogs. It is not normally found in cat urine

b. Bilirubin is derived from the breakdown of heme by the reticuloendothelial system
c. Bilirubin may appear in the urine prior to the observation of hyperbilirubinemia
d. Causes of bilirubinuria include hemolysis, liver disease, extrahepatic biliary obstruction, fever, and starvation

6. Blood
a. Positive earlier than the observation of hematuria
b. Dipstick tests do not differentiate from intact RBCs or hemoglobin
c. Causes of hemoglobinuria from hemolysis include transfusion reaction, immune mediated hemolytic anemia, disseminated intravascular coagulopathy (DIC), splenic torsion, severe hypophosphatemia, heat stroke, zinc toxicity, and phosphofructokinase or pyruvate kinase deficiency

C. Urinary sediment
1. Sediment preparation
a. Perform on fresh urine samples
b. Centrifuge 5 to 10 mL of urine at 1000 to 1500 rpm for 5 minutes. Stain with Sedi-Stain
c. Number of casts is recorded per low-power field, and cells are recorded per high-power field

2. RBCs
a. Occasional RBCs are normal
b. Excessive number of RBCs is called *hematuria*, but origin cannot be determined
c. Lipid droplets are often confused with RBCs, especially in cats
d. Causes of hematuria include trauma, urolithiasis, neoplasia, UTIs idiopathic feline lower urinary tract disease, chemically induced cystitis, systemic diseases associated with hemorrhage, renal infarct, nephritis, nephrosis, parasites, renal pelvic hematoma, or genital tract contamination

3. White blood cells (WBCs)
a. Occasional WBCs are normal
b. Excessive WBCs in urine sediment is called *pyuria* and indicates inflammation somewhere in the urinary tract or contamination from the genital tract
c. Clumped WBCs are typically due to infectious organisms
d. Causes of pyuria include urinary tract inflammation or genital tract contamination

4. Epithelial cells
a. Squamous epithelial cells
(1) Large, polygonal cells with small, round nuclei
(2) Common in voided or catheterized samples
b. Transitional epithelial cells
(1) A small number is normal
(2) Increased in infection, irritation, or neoplasia
(3) Clumps or "rafts" are most common in neoplasia but may occur with inflammation
c. Renal epithelial cells
(1) Small epithelial cells from the renal tubules or pelvis
(2) Appearance in urine is never normal and is observed in patients with ischemic, nephrotoxic, or degenerative renal disease

5. Casts are cylindrical molds of the renal tubules composed of aggregated protein or cells
a. Hyaline
(1) Pure protein precipitates of Tamm-Horsfall mucoprotein
(2) Dissolve rapidly in dilute or alkaline urine
(3) Have the least pathologic significance and may form transiently with fever, exercise, or passive congestion to the kidney
b. Cellular casts
(1) White cell casts suggest pyelonephritis but may also be caused by interstitial nephritis, nephrosis, or glomerulonephritis
(2) Red cell casts are fragile and rarely found. They may be noted in acute glomerulonephritis, renal trauma, or after violent exercise
(3) Hemoglobin casts are casts where the hemoglobin color is retained in the cast
(4) Renal epithelial casts occur with severe tubular injury and suggest acute tubular necrosis or pyelonephritis (Figure 1-1)
(5) Renal fragments are a variant of epithelial casts where portions of the renal tubules slough into urine. Their appearance suggests severe renal injury
(6) Mixed casts contain multiple cell types
c. Granular casts (Figure 1-2)
(1) Represent the degeneration of cells or precipitation of filtered plasma proteins
(2) Fatty casts are a type of granular cast that may be seen in nephrotic syndrome or diabetes mellitus

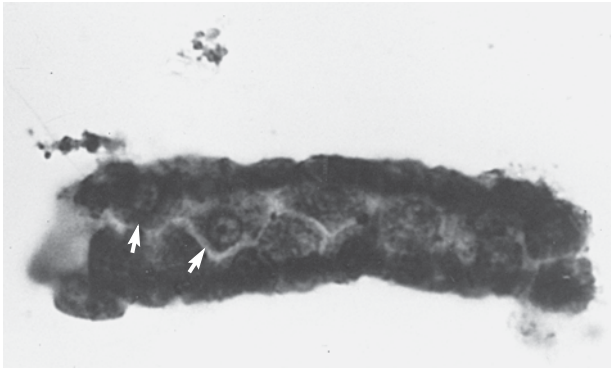


Figure 1-1 Photomicrograph of an epithelial cell cast in urine. Small renal epithelial cells can be identified in this case *(white arrows).* (Courtesy Nancy Facklam; from Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

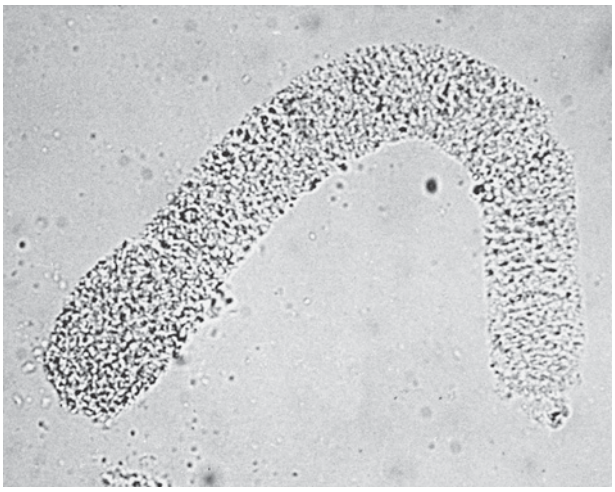


Figure 1-2 Photomicrograph of a finely granular case in urine. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

 d. Waxy casts represent the final stage of degeneration of granular casts. They suggest chronic intrarenal stasis and are found in advanced chronic renal disease
 e. Broad casts are wide casts that form in collecting ducts or dilated distal nephron. They suggest severe intrarenal stasis and tubular obstruction
6. Organisms
 a. Normal urine is sterile
 b. Large numbers of bacteria present (in association with pyuria) in urine collected by catheterization or cystocentesis strongly suggest the presence of UTI
 c. The presence of bacteria without pyuria should arouse suspicion for bacterial contamination. However, dogs with hyperadrenocorticism, diabetes mellitus, or immunosuppression and cats with chronic renal disease can have bacteriuria with pyuria
 d. The absence of bacteria does not rule out UTI
 e. Yeast and fungal hyphae in sediment are usually contaminants
7. Crystals
 a. Crystals are often an artifact of storage time and refrigeration
 b. Struvite crystals are found in alkaline urine and may be found in normal animals or in those with struvite urinary stones
 c. Calcium phosphate crystals are found in alkaline urine
 d. Calcium carbonate crystals are found in alkaline urine
 e. Amorphous phosphate crystals are found in alkaline urine
 f. Ammonium biurate crystals are found in alkaline urine
 g. Uric acid crystals are found in acidic urine and are associated with the Dalmatian breed
 h. Urate crystals are associated with liver disease and portosystemic shunt
 i. Calcium oxalate crystals are found in acidic urine
 j. Cystine crystals are found in acidic urine and are associated with cystinuria
 k. Bilirubin crystals may be found normally in concentrated dog urine
 l. Oxalate monohydrate ("hippurate-like") crystals are found in acute renal failure owing to ethylene glycol ingestion
8. Miscellaneous
 a. Sperm is common in urine from intact males
 b. Amorphous debris may be seen in those with acute intrinsic renal failure
 c. Mucous threads or fibrin strands may be seen in association with lower urinary tract or genital inflammation
 d. Parasite ova from *Dioctophyma renale* or *Capillaria plica* are rarely seen
 e. Lipid droplets are associated with cellular degeneration
 f. Foreign material may be present, especially in voided samples
 g. Precipitates of urine stain may look like urinary crystals

FLUIDS AND ACID-BASE METABOLISM

I. Dehydration
 A. Status
 1. Total body water is about 60% of body weight; about half is extracellular and half is intracellular
 2. Very mild dehydration occurs with water loss of 1% to 4% of body weight. Clinical signs are not detectable
 3. Mild dehydration occurs with water loss of 5% to 6% of body weight. Clinical signs include dry mucous membranes, slight loss of skin turgor, injected conjunctiva, and inelasticity of skin
 4. Moderate dehydration occurs with water loss of 7% to 9% of body weight. Clinical signs include loss of skin turgor with slow return, prolonged capillary refill time (2-3 seconds), enophthalmos
 5. Severe dehydration occurs with water loss of 10% to 12% of body weight. Clinical signs include extreme loss of skin turgor, peripheral vasoconstriction, cold extremities, and prolonged capillary refill time (>3 seconds)
 6. Very severe dehydration occurs with water loss of 13% to 15% of body weight; clinical signs include vascular collapse, renal failure, and death
 B. Isotonic dehydration occurs with equal losses of water and solute
 1. Sodium and chloride concentrations are not affected
 2. Increased packed cell volume (PCV) with increased plasma proteins
 3. Occurs in some cases of diarrhea and renal disease

C. Hypertonic dehydration occurs when more water than solute is lost
 1. Concentration of sodium and chloride increases
 2. PCV increases, with increased plasma proteins
 3. Occurs most commonly in diabetes insipidus
 4. Species that produce hypotonic sweat (cattle) or little sweat (dogs, cats) develop hypertonic dehydration with heat stress

D. Hypotonic dehydration occurs when more solute than water is lost
 1. Concentrations of sodium and chloride decrease
 2. This results in a contraction of the extracellular fluid (ECF) volume with expansion of intracellular fluid (ICF) volume to restore osmotic equilibrium
 3. Most common type of dehydration, where the solute loss induces a secondary loss of water
 4. Hypotonic dehydration from heat stress occurs in species that produce hypertonic sweat (horses)

II. Acid-base metabolism

A. Henderson-Hasselbach equation
 1. $pH = pK_a + \log [A^-]/[HA]$
 2. The carbonic acid-bicarbonate system is usually used: $pH = pK_a + \log [HCO_3^-]/[H_2CO_3]$
 3. $pH = 6.1 + \log[HCO_3^-]/0.03(P_{CO_2})$

B. To characterize acid-base disorders, blood pH, HCO_3, and P_{CO_2} are measured (Table 1-1)
 1. A decrease in pH is acidosis; an increase is alkalosis
 2. A decrease in HCO_3 is a metabolic acidosis; an increase is a metabolic alkalosis
 3. A decrease in P_{CO_2} is a respiratory alkalosis; an increase is a respiratory acidosis
 4. If HCO_3 measurement is unavailable, total CO_2 from a chemistry profile can be used as an estimate. Total CO_2 is about 1 to 2 mmol/L greater than the HCO_3 concentration

C. Metabolic disorders
 1. Characterized by changes in HCO_3
 2. Compensation is via rapid changes in ventilation to alter P_{CO_2}

D. Respiratory disorders
 1. Characterized by changes in P_{CO_2}
 2. Compensation is via a change in urinary acidification to alter HCO_3. This process is slower than compensation in ventilation

E. Simple acid-base disorders occur when there is a primary change, but no compensation has taken place

F. Compensated acid-base disorders occur when primary changes are present, along with evidence of a compensatory change in the complementary system. The pH rarely returns to normal with compensation

G. Combined acid-base disorders occur when there are changes in the same direction in both systems

H. Metabolic acidosis
 1. Primary change is decreased HCO_3
 2. P_{CO_2} will decrease in compensation

I. Metabolic alkalosis
 1. Primary change is increased HCO_3
 2. P_{CO_2} will increase in compensation

J. Respiratory acidosis
 1. Primary change is increased P_{CO_2}
 2. HCO_3 will increase in compensation
 3. There is a larger compensation in chronic respiratory acidosis compared with an acute event

K. Respiratory alkalosis
 1. Primary change is decreased
 2. P_{CO_2}
 3. HCO_3 will decrease in compensation
 4. There is a larger compensation in chronic respiratory alkalosis compared with an acute event

L. Base excess and base deficit
 1. Calculated from blood gas parameters by the blood gas analyzer. This calculation is based on human relationships and is probably valid for dogs and cats. This calculation might not be valid for other species
 2. Increased values reflect a base excess corresponding to metabolic alkalosis
 3. Decreased values reflect a base deficit, corresponding to metabolic acidosis

M. Anion gap
 1. Anion gap = (Na + K) – (Cl + HCO_3); the objective is to estimate changes in the unmeasured anions and cations without having to measure them
 a. Unmeasured anions include sulfate, lactate, phosphate, pyruvate, albumin, and ketoacids
 b. Unmeasured cations include primarily calcium and magnesium
 2. If the anion gap increases, then unmeasured anions have increased. If the anion gap decreases, then unmeasured cations have increased

III. Osmolality

A. *Osmolality* is the concentration or number of osmotically active particles in an aqueous solution

B. *Osmolal gap* is the difference between the actual measured serum osmolality and the calculated estimate of osmolality

Table 1-1 Characteristics of Primary Acid-Base Disturbances

	pH	$[H^+]$	$[HCO_3]$	P_{CO_2}
Metabolic alkalosis	↑	↓	↑↑	↑
Metabolic acidosis	↓	↑	↓↓	↓
Respiratory acidosis	↓	↑	↑	↑↑
Respiratory alkalosis	↑	↓	↓	↓↓
GI loss (vomiting, diarrhea)				

Primary events are indicated by double arrows.

1. Calculated osmolality (mOsm/L) = 1.86 [Na (mmol/L)] + [glucose (mg/dL)/18] + [BUN (mg/dL)/2.8] + 9
2. The osmolal gap increases when there is an increase in any osmotically active particles that are not included in the calculated equation
3. The osmolal gap will increase whenever the anion gap is increased
4. Used commonly in cases of ethylene glycol toxicity
 a. Ethylene glycol is a small osmotically active particle
 b. The osmolal gap correlates well with the concentration of ethylene glycol in serum

ELECTROLYTE METABOLISM

I. Sodium
 A. Roles
 1. Principal cation in ECF
 2. Important in movement of fluids across epithelial surfaces
 B. Hyponatremia
 1. Pseudohyponatremia
 a. Occurs with hyperlipidemia or hyperproteinemia
 b. Plasma sample is diluted by the excess lipid or protein and thus the measured sodium concentration is falsely lowered
 2. Hyperosmolal, hypervolemic conditions include hyperglycemia and mannitol administration
 3. Hypoosmolal hypervolemic conditions
 a. Occurs when there is excess water retention with dilution of the plasma
 b. Causes include nephrotic syndrome, chronic liver disease, chronic renal failure, and congestive heart failure
 4. Hypoosmolal euvolemic conditions include hypotonic fluid infusion,antidiuretic hormone (ADH) administration, inappropriate secretion of ADH, and psychogenic polydipsia
 5. Hypoosmolal hypovolemic conditions include the following:
 a. Dietary deficiency of sodium
 b. GI loss from vomiting or diarrhea
 c. Third-space syndrome (GI obstruction, peritonitis, uroabdomen, ascites)
 d. Urinary loss from hypoadrenocorticism, nonoliguric acute renal failure, diuretics, and Fanconi syndrome
 e. Cutaneous losses (burns)
 C. Hypernatremia
 1. Pure water deficits occur in dietary deficiency, central or nephrogenic diabetes insipidus, primary hypodipsia, heat stress, and fever
 2. Hypotonic fluid loss occurs with the following:
 a. GI loss owing to vomiting or diarrhea
 b. Third-space syndrome (peritonitis, ascites)
 c. Urinary loss from osmotic diuretics (mannitol, diabetes mellitus), chronic renal failure, nonoliguric acute renal failure, postobstructive nephropathy
 d. Cutaneous loss (burns)
 3. Solute gain occurs with salt poisoning, hypertonic fluid administration, hyperadrenocorticism, hyperaldosteronism
II. Chloride
 A. Roles
 1. Principal anion in ECF
 2. Chloride usually accompanies sodium to maintain neutrality
 3. Normal fractional excretion is less than 1% but may be elevated in large animals fed a diet higher in chlorine
 B. The same conditions causing hypernatremia and hyponatremia also cause hyperchloremia and hypochloremia
III. Potassium
 A. Roles
 1. Principal cation of the ICF
 2. Determines resting cell membrane potential
 B. Hypokalemia (typically associated with alkalosis)
 1. Decreased intake
 a. Anorexia
 b. Dietary deficiency
 c. Administration of potassium-free fluids
 2. Translocation between ECF and ICF
 a. Metabolic alkalosis, respiratory alkalosis
 b. Glucose or insulin administration
 c. Catecholamines
 3. Increased loss
 a. GI loss
 (1) Vomiting
 (2) Diarrhea
 b. Third-space syndrome
 (1) GI obstruction (especially displaced abomasum)
 (2) Peritonitis
 (3) Ascites
 c. Urinary loss
 (1) Hyperadrenocorticism
 (2) Acute renal failure (nonoliguric)
 (3) Postobstructive diuresis
 (4) Chronic renal failure (cats)
 (5) Potassium-losing diuretics
 (6) Fanconi syndrome
 (7) Renal tubular acidosis
 (8) Primary hyperaldosteronism
 d. Cutaneous loss (burns)
 4. Feline kaliopenic nephropathy-polymyopathy syndrome
 a. Characterized by hypokalemia, increased fractional excretion of potassium, azotemia, and metabolic acidosis
 b. Chronic decrease of potassium leads to decrease in aldosterone, which leads to distal renal tubular acidosis
 C. Hyperkalemia (typically associated with acidosis)
 1. Pseudohyperkalemia (in *vitro* translocation of potassium to plasma)
 a. Thrombocytosis
 b. Leukemia
 c. Hemolysis (equine, bovids)
 d. Akita dogs

2. Increased intake or oversupplementation of fluids with potassium
3. Translocation between ICF and ECF
 a. Respiratory or metabolic acidosis
 b. Hyperkalemic periodic paralysis
 c. Ischemia or reperfusion injury
4. Decreased urinary excretion
 a. Anuric or oliguric renal failure
 b. Urinary tract obstruction
 c. Ruptured urinary bladder
 d. Hypoadrenocorticism
 e. Potassium-sparing diuretics
 f. Nonsteroidal antiinflammatory drugs (NSAIDs)
 g. Angiotensin-converting enzyme (ACE) inhibitors

IV. Phosphorus
A. Roles
1. Found mostly in ICF
2. Regulated through interactions with calcium and calcium metabolic hormones
 a. Calcitriol increases phosphorus resorption from bone, increases GI phosphorus absorption, and increases urinary fractional excretion of phosphorus
 b. The concentrations of calcium and phosphorus are reciprocally related and are kept relatively constant

B. Hypophosphatemia
1. Increased cellular uptake of phosphorus (glucose administration)
2. Acid-base balance
 a. Respiratory alkalosis
 b. Metabolic acidosis (enhanced urinary excretion of phosphates); often in diabetic ketoacidosis
3. Abnormalities in renal tubular phosphate reabsorption
 a. Hyperparathyroidism
 b. Fanconi syndrome
 c. Aminoglycoside nephrotoxicosis
4. GI absorption
 a. Decreased phosphorus in diet
 b. Vomiting
 c. Diarrhea
 d. Intestinal malabsorption syndromes
 e. Excessive ingestion of phosphate binders

C. Hyperphosphatemia
1. Redistribution between ICF and ECF
2. Cellular damage
3. Acute acidosis (chronic metabolic acidosis causes hypophosphatemia usually)
4. Decreased renal blood flow and GFR (resulting in secondary hyperparathyroidism)
5. Ruptured urinary bladder
6. Hypertonic sodium phosphate enemas
7. Excessive dietary intake (with secondary hyperparathyroidism)

V. Magnesium
A. Roles
1. Magnesium is an important cofactor for many enzymatic reactions
2. Influences cell membrane properties

B. Hypomagnesemia
1. Most often occurs after excessive magnesium loss
 a. GI tract (malabsorption syndromes, diarrhea)
 b. Renal loss (fluid diuresis, diuretic therapy, renal disease)
2. Iatrogenic deficiency occurs during fluid therapy as most fluids contain little or no magnesium
3. Metabolic disorders (diabetes mellitus, primary hyperparathyroidism, primary hypoparathyroidism, hyperaldosteronism, third-space syndrome, hypophosphatemia)
4. Ruminants
 a. *Milk tetany*, in which calves are fed a magnesium-deficient milk diet
 b. *Grass tetany*, which occurs in adults fed on lush, green pasture that is high in potassium, which blocks magnesium absorption from the rumen

C. Hypermagnesemia
1. Renal disease (both acute and chronic)
2. Increased renal tubular reabsorption of magnesium during dehydration, salt depletion, and hypoadrenocorticism
3. Overadministration of magnesium-containing antacids

VI. Calcium
A. Roles
1. Major structural role in the skeleton
2. Important in regulation of ions across membranes
3. Cofactor in many metabolic processes
4. Major role in signal transmission, skeletal muscle contraction, and cardiovascular function

B. Measurement of calcium
1. Ionized calcium should be measured for an accurate assessment of calcium status
2. Adjustment formulas for total calcium should not be used because they do not reliably predict ionized calcium concentration
3. Acidosis increases ionized calcium concentration, and alkalosis decreases ionized calcium concentration

C. Hypocalcemia
1. Primary hypoparathyroidism is characterized by hypocalcemia with a low or low-normal concentration of parathyroid hormone (an inappropriate response). Hypomagnesemia may also be seen. Primary hypoparathyroidism can be spontaneously occurring; result from parathyroiditis or parathyroid adenoma infarction; or occur postoperatively after removal of a parathyroid adenoma or any other neck surgery that can interrupt the blood supply to the parathyroid glands
2. Common causes of hypocalcemia include hypoalbuminemia, chronic renal failure (ionized hypocalcemia), eclampsia, acute renal failure, acute pancreatitis, and urethral obstruction in cats

3. Occasional causes of hypocalcemia include soft tissue trauma, rhabdomyolysis, ethylene glycol poisoning, phosphate enemas, post bicarbonate administration, and critical illness or sepsis
4. Uncommon causes of hypocalcemia include EDTA contamination, dilution with calcium-free IV fluids, intestinal malabsorption, hypovitaminosis D, pancreatitis, citrated blood transfusions, hypomagnesemia, and tumor lysis syndrome

D. Hypercalcemia
1. Neoplasia is the most common cause of ionized hypercalcemia in dogs. Neoplasia is characterized by an elevation of both total and ionized calcium, with parathyroid hormone suppressed into the lower part of or below the reference range (a parathyroid- independent hypercalcemia)
 a. In dogs, the most common neoplasm causing hypercalcemia is lymphoma. Other neoplasms include anal sac apocrine gland adenocarcinoma, thymoma, carcinomas (lung, pancreas, mammary gland, skin, nasal cavity, thyroid, adrenal medulla), and hematologic malignancies (multiple myeloma, lymphoma, myeloproliferative disease, leukemia)
 b. In cats, the most common neoplasias are lymphoma and squamous cell carcinomas. Other neoplasms include multiple myeloma, leukemia, osteosarcoma, fibrosarcoma, and bronchogenic carcinoma
2. Idiopathic hypercalcemia is the most common cause of ionized hypercalcemia in cats. Idiopathic hypercalcemia is also a parathyroid independent hypercalcemia
3. Renal disease is a common cause of an elevation of serum total calcium but not ionized calcium. With renal disease, serum ionized calcium concentration is typically normal to low
4. Vitamin D toxicity from oversupplementation with vitamin D, ingestion of plants containing calcitriol glycosides (*Cestrum diurnum*), ingestion of cholecalciferol rodenticides, or ingestion of antipsoriasis cream (Dovonex). Vitamin D toxicity is a parathyroid-independent hypercalcemia, and an elevation in phosphorus is typically observed
5. Primary hyperparathyroidism causes an elevation of both serum total and ionized calcium with lack of suppression of parathyroid hormone production. Parathyroid hormone concentration may be still within normal limits, or it may be elevated
6. Other causes of hypercalcemia include hypoadrenocorticism, osteolytic processes, granulomatous disease, grape or raisin toxicity, dehydration, vitamin A toxicity, aluminum toxicity, excessive calcium carbonate supplementation, intestinal phosphate binders, thiazide diuretics, acromegaly, or severe hypothermia

EVALUATION OF THE LIVER

I. Enzymes in the liver
 A. Leakage enzymes: alanine aminotransferase (ALT), aspartate aminotransferase (AST), sorbitol dehydrogenase (SDH), and glutamate dehydrogenase (GLDH)
 B. Induced enzymes: alkaline phosphatase (ALP), GGT

II. Tests for hepatocyte injury
 A. Alanine aminotransferase (ALT)
 1. Previously called serum pyruvic transaminase (SGPT)
 2. Not liver specific; leakage enzyme
 3. In dogs and cats, ALT is present mostly in hepatocytes, but increases can be seen with muscle injury (especially extensive injury)
 4. Horses and ruminants have little ALT in hepatocytes, so elevations of ALT usually indicate muscle damage
 B. Aspartate aminotransferase (AST)
 1. Previously called serum glutamic oxaloacetic transaminase (SGOT)
 2. Present in hepatocytes and in skeletal and cardiac muscle cells
 3. Not liver specific; leakage enzyme
 4. Increased AST can be due to hepatocyte death, hepatocyte injury, muscle cell death and muscle cell injury
 5. Not as specific in the dog and cat as ALT; more specific than ALT in horses and ruminants
 C. Sorbitol dehydrogenase (SDH)
 1. Liver specific; leakage enzyme
 2. Increase suggests hepatocyte death or injury
 3. Very short half-life, and values return to normal within a few days
 4. Not very stable in serum samples; stable for about 48 hours if frozen
 5. In horses and ruminants, SDH is preferable to AST for detecting injury to hepatocytes
 D. Glutamate dehydrogenase (GLDH)
 1. Liver specific; leakage enzyme
 2. Increase suggests hepatocyte death or injury
 3. More stable than SDH but still not very stable

III. Tests for cholestasis
 A. ALP is an induced enzyme
 1. Bone origin (BALP)
 a. Mild increase associated with increased osteoblast activity
 b. Will be higher in young growing animals
 c. May be elevated in association with primary or secondary hyperparathyroidism (effects of PTH on bone)
 2. Liver origin (LALP)
 a. An increase is associated with cholestasis
 b. LALP usually increases before an increase in bilirubin with cholestasis
 3. Corticosteroid-induced (CiALP)
 a. Induced by corticosteroids and also anticonvulsants
 b. Chronic disease (including chronic cholestasis) can induce CiALP

4. In cats, the half-life of ALP is very short (about 6 hours); thus the increase of ALP in cholestatic disease is significantly less than in other species
5. Increases in horses with cholestasis are not well documented
6. In ruminants, increases in ALP are usually due to cholestasis or osteoblastic activity

B. GGT
1. Considered to be an induced enzyme; however, acute injury can cause elevations of GGT
2. Elevated primarily in cholestasis. May also be induced by glucocorticoids and anticonvulsants
3. GGT is superior to ALP in horses and ruminants for the detection of cholestasis
4. GGT is present in very high levels in cattle and sheep colostrums, resulting in very high levels of serum GGT in calves and sheep that have consumed colostrum

IV. Tests of liver function

A. Bilirubin
1. Normal metabolism
 a. The heme portion of hemoglobin is split into iron and protoporphyrin
 b. Protoporphyrin is converted to biliverdin, then to bilirubin
 c. Bilirubin is released from macrophages, attached to albumin or other globulins, transported to the liver, released from albumin or globulins, and enters hepatocytes. This circulating bilirubin is termed *unconjugated* or *indirect*. Most bilirubin in horses is unconjugated
 d. Once in hepatocytes, bilirubin is conjugated, and most is secreted into bile. A small amount passes through the sinusoidal side back into the blood. Conjugated bilirubin is also termed *direct bilirubin*
2. Abnormal metabolism
 a. Historically, both unconjugated and conjugated bilirubin have been measured, but currently a total bilirubin measurement is usually determined
 b. Bilirubin is increased when there is increased hemoglobin production (increased RBC destruction), decreased uptake and conjugation of bilirubin by hepatocytes, and a decrease in outflow of conjugated bilirubin (cholestasis, etc.)
 c. Bilirubin is not consistently elevated in ruminants with liver disease

B. Bile acids
1. Fasting and postprandial samples are usually collected in dogs and cats
2. The postprandial bile acid concentration is usually greatly exaggerated with portosystemic shunt
3. Increases in fasting, postprandial, or both samples may occur with portosystemic shunts, cholestasis, cirrhosis, necrosis, hepatitis, hepatic lipidosis, steroid hepatopathy, and neoplasia (Figure 1-3)

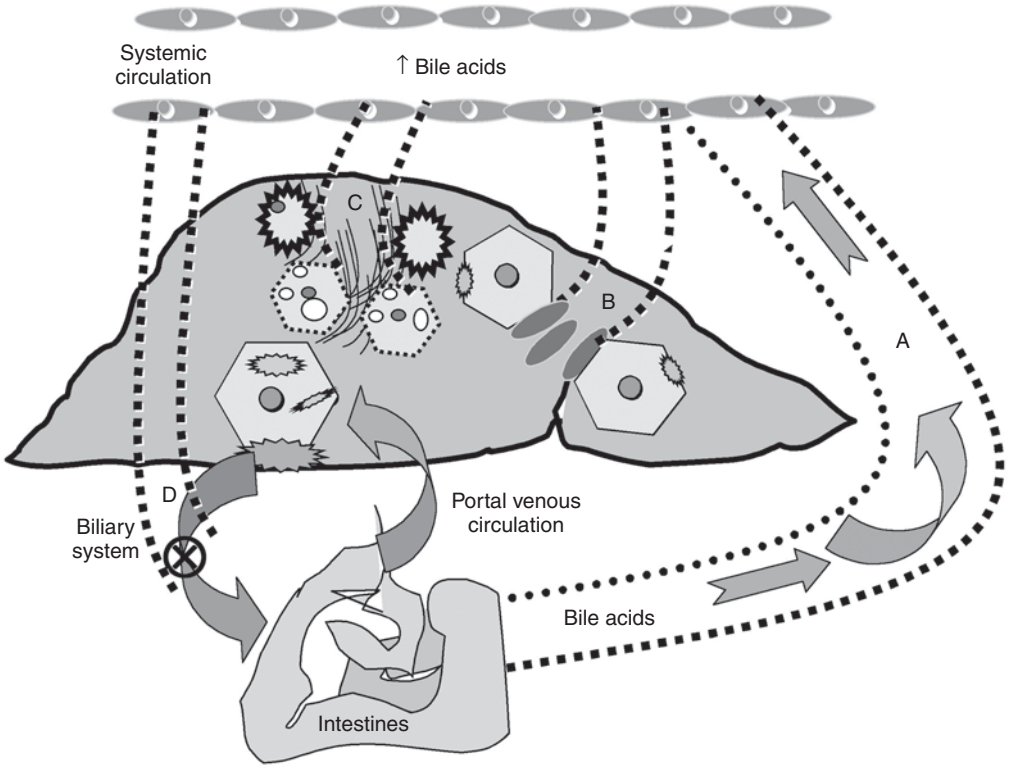


Figure 1-3 The increase in the bile acid level in the circulation is generally caused by one of four disorders: congenital portosystemic shunting **(A)**, hepatic microvascular dysplasia **(B)**, intrahepatic colestatic disease **(C)**, or extrahepatic bile duct obstruction **(D)**. (From Meyer D, Harvey JW. *Veterinary Laboratory Medicine: Interpretation and Diagnosis,* 3rd ed. St Louis, 2004, Saunders.)

4. One sample is collected in horses and ruminants. An increase in bile acids suggests hepatic disease

C. Ammonia concentration is usually increased in those with portosystemic shunts or if more than 60% of liver mass is lost
D. Albumin decreases when 60% to 80% of liver function is lost
E. Globulins may be increased, especially in horses
F. Glucose
1. The liver converts glucose to glycogen
2. Glucose may be increased if there is decreased glucose uptake by the liver
3. Glucose may be decreased if there is decreased gluconeogenesis or glycogenolysis
G. Urea is synthesized in the liver from ammonia
1. BUN decreases with liver failure
2. Blood ammonia concentration increases with liver failure
H. Cholesterol
1. Can be decreased if there is decreased synthesis of cholesterol with liver failure
2. Can be increased if cholestasis is present, which prevents excretion of cholesterol in bile
I. Coagulation factors are commonly decreased in dogs with liver failure

V. Changes in selected liver diseases
A. Portosystemic shunt
1. If portosystemic shunts occur because of severe cirrhosis, then changes as seen in end-stage liver disease are expected
2. Early portosystemic shunts do not cause much active hepatocyte damage; thus leakage enzymes are usually not elevated
a. Induced enzymes are also not elevated because there is little cholestasis
b. Typically occurs in young, growing animals, so ALP may be elevated (BALP)
c. Bile acids are markedly elevated
d. Microcytic anemia with low iron concentration is typical
B. Hepatic necrosis
1. If focal, leakage enzymes may be normal or mildly elevated
2. Diffuse necrosis more often results in elevations in both leakage and induced enzymes.
C. Hypoxia or mild toxic damage
1. This process is diffuse, so leakage enzymes are usually mildly to moderately elevated
2. Induced enzymes and bilirubin are not typically elevated
3. Bile acids may be mildly increased
D. Focal lesions
1. Leakage enzymes may be normal to mildly increased
2. Induced enzymes are usually normal unless bile flow is significantly impaired
E. Hepatic lipidosis
1. Leakage enzymes are increased in most cats
2. ALP is also elevated in most, but GGT is elevated in only a small number
3. Serum bilirubin is usually elevated, and bile acids are commonly increased
F. Steroid hepatopathy
1. Most common in dogs
2. Leakage enzymes are mildly increased
3. Induced enzymes are markedly increased
4. Bilirubin may be mildly increased
G. Biliary disorders
1. Induced enzymes are markedly increased
2. Leakage enzymes may be mildly increased as a result of hepatocyte injury from the cholestasis
3. Bilirubin and bile acids are also typically increased
H. Chronic liver disease
1. Leakage enzymes may be increased, depending on the extent and rate of progression of the disease
2. Induced enzymes are usually mildly to moderately increased
3. Bilirubin concentration is normal to mildly increased in those with more advanced disease
I. End-stage liver disease
1. Occurs when 60% to 80% of liver mass has been lost
2. Leakage enzymes may be normal to mildly increased because of the overall loss of liver mass
3. Induced enzymes are moderately to markedly increased, as are bilirubin and bile acid concentrations
4. Many have increased ammonia, decreased BUN, decreased albumin, and abnormal coagulation tests

EVALUATION OF THE PANCREAS

I. Pancreatic injury
A. Serum amylase
1. Dogs
a. Highest concentrations in pancreas and small intestinal mucosa
b. Causes of increased serum amylase include pancreatic injury, renal dysfunction, GI disease, hepatic disease, and neoplasia (lymphoma, hemangiosarcoma)
c. Magnitude of the increase may be helpful. If amylase is elevated more than three-fold greater than the upper reference range limit, pancreatic injury is strongly suggested
2. Other species
a. Amylase is usually normal in cats with pancreatic injury and may be decreased
b. Amylase is only slightly elevated in horses with pancreatic injury and is elevated in most horses with proximal enteritis and other causes of colic
B. Serum lipase
1. Dogs
a. Causes of increased serum lipase include pancreatic injury, renal dysfunction, hepatic disease, GI disease, corticosteroids (dexamethasone can increase lipase five-fold), and neoplasia (lymphoma, hemangiosarcoma)

b. An elevation greater than two-fold is suggestive of pancreatic injury, except if the dog has received corticosteroids
2. Cats with pancreatic injury typically have normal lipase activity

C. Peritoneal fluid
1. If amylase or lipase activity is higher in peritoneal fluid than in serum, pancreatic injury is more likely
2. Consider measuring in cats or horses with suspected pancreatic injury

D. Serum trypsin-like immunoreactivity (TLI)
1. TLI activity is proportional to trypsinogen and trypsin. Trypsinogen is secreted only by the pancreas and is converted to trypsin in the small intestine
2. TLI is increased in pancreatitis and is a more sensitive indicator of early pancreatitis than are amylase or lipase determination
3. TLI is also a sensitive and specific indicator for pancreatitis in the cat

II. Exocrine pancreatic insufficiency (see section below on intestinal absorption)

EVALUATION OF DIGESTION AND INTESTINAL ABSORPTION

I. Fecal parasites
A. Refrigerate fecal sample if cannot examine within 2 hours
B. Direct smears are useful in detecting *Strongyloides*, *Coccidia, Giardia*, *Balantidium*, *Entamoeba*, and *Trichomonas* spp.
C. Wet mounts are useful to detect *Giardia*, *Balantidium*, and *Entamoeba* spp.
D. Fecal flotation
1. Best method for detecting parasitic ova and oocysts
2. Different fecal flotation solutions can be used, including a sugar solution, sodium chloride, magnesium sulfate, zinc sulfate, or sodium nitrate solutions

E. Baermann technique is most useful for detection of larvae in feces.

II. Fecal occult blood
A. Performed in animals with chronic diarrhea or loose stools, microcytic anemia, a history of GI tumors, or in those treated with NSAIDs
B. Positive test result suggests upper GI tract inflammation, ulceration, or neoplasia
C. False positives may occur when consuming meats or some vegetables. It is best to restrict the diet (rice and cottage cheese) for a few days before the test

III. Fecal cytology
A. Look for types of bacteria present
B. Evaluate for presence of inflammatory cells

IV. Digestion and absorption tests
A. Fecal starch
1. Stain feces with Lugol solution
2. The presence of undigested starch suggests a deficiency in starch-digesting enzymes or increased intestinal motility
3. Dependent on the quantity of starch in the diet

B. Fecal fat
1. Direct fecal fat detects undigested fat
a. Stain feces with Sudan III or IV on slide and examine
b. The presence of undigested fecal fat indicates a deficiency in lipase
2. Indirect fecal fat detects digested fat
a. Mix feces, acetic acid, and Sudan III or IV on a slide; bring to a boil and examine
b. The presence of digested fat (in the absence of undigested fat) suggests adequate lipase production but inadequate absorption of fat

C. Fecal proteolytic activity can be estimated but is rarely performed anymore since the advent of serum TLI determination
D. Fecal muscle fibers
1. Stain brown with Lugol stain
2. Presence suggests inadequate fecal protease activity

E. Fat absorption test (plasma turbidity test)
1. After a 12-hour fast, orally administer corn oil, then collect hourly plasma samples for a few hours
2. Turbidity of the samples should occur, indicating the absorption of lipid
3. If turbidity does not occur, then repeat test with corn oil that has been preincubated with pancreatic enzymes. If turbidity occurs, then absorption occurred and the problem is with digestion of fat
4. The sensitivity of this test is poor

F. Serum TLI
1. Available for dogs and cats
2. TLI is decreased in dogs and cats with EPI. It is normal in other small intestinal diseases

G. D-Xylose absorption test
1. Measure of intestinal absorption in dogs and horses
2. Xylose absorption is falsely decreased in those with delayed gastric emptying, bacterial overgrowth, and in some with exocrine pancreatic insufficiency (EPI)

H. Vitamin B_{12} and folate assays
1. Serum folate is decreased if there is malabsorption in the proximal small intestine
2. Serum vitamin B_{12} is decreased if the malabsorption is primarily in the distal small intestine
3. In cats with EPI, both serum vitamin B_{12} and folate levels are usually decreased. In dogs with EPI, serum vitamin B_{12} is usually decreased, and folate is usually normal to increased
4. In small intestinal bacterial overgrowth, vitamin B_{12} is decreased and folate is increased

EVALUATION OF SERUM AND PLASMA PROTEINS

I. Plasma versus serum
A. Plasma contains albumin, and all globulins, which include antibodies, clotting factors, enzymes, and proteins

B. Serum contains no fibrinogen and only contains albumin and remaining globulins

II. Total protein concentration
A. Can be measured with a refractometer. Excess lipid, hemoglobin, bilirubin, glucose, urea, sodium, or chloride can falsely increase total protein concentration as measured by refractometry
B. Spectrophotometric measurement is more accurate

III. Albumin concentration
A. Measured spectrophotometrically
B. At very low concentrations, albumin may be overestimated

IV. Globulin concentrations
A. Fractions
1. The α-fraction includes thyroxine-binding globulin, transcortin, some lipoproteins (LPs), ceruloplasmin, haptoglobin, antithrombin III, and α_2-macroglobulin
2. The fraction includes some LPs, transferrin, ferritin, C-reactive protein, complement C3 and C4, plasminogen, and fibrinogen (in plasma only)
3. The γ-fraction includes the immunoglobulins
B. Measurement
1. The globulin concentration reported on a chemistry profile is calculated by subtracting serum albumin from total protein concentration
2. Accurate measurement is determined by serum protein electrophoresis
3. Estimation of immunoglobulins
a. Refractometry
(1) Not reliable in foals
(2) Cutoff value for plasma protein concentration that indicates adequate passive transfer
(3) Dehydration can falsely elevate plasma protein concentration
b. Sodium sulfite precipitation test
(1) Determines three general ranges for immunoglobulin quantities in calves
(2) Not reliable for foals
c. Zinc sulfate turbidity test
(1) Can be used in both calves and foals
(2) Better tests available
d. Glutaraldehyde coagulation test
(1) Used in calves and foals
(2) Use serum

V. Fibrinogen concentration
A. Most common method is by heat precipitation
B. Can also measure in citrated blood (expensive, not routinely used)

VI. Abnormal concentrations
A. Decreased protein concentrations
1. Hypoalbuminemia with hypoglobulinemia. Causes include blood loss, protein-losing enteropathy, severe exudative skin disease, severe burns, and effusive disease
2. Hypoalbuminemia with normal or increased globulins. Causes include starvation, liver disease, GI parasites, intestinal malabsorption, exocrine pancreatic insufficiency, and glomerular disease (loss of albumin)
3. Hypoglobulinemia with normal or increased albumin. Causes include failure of passive transfer, and immune deficiencies (inherited or acquired)
B. Increased protein concentrations
1. Hyperalbuminemia occurs only in dehydration
2. Hyperalbuminemia with hyperglobulinemia occurs in dehydration
3. Hyperglobulinemia
a. Increased α-globulin concentration occurs most commonly in acute inflammation
b. Increased β-globulin concentration occurs in acute inflammation, nephrotic syndrome, liver disease, and immune responses
c. Increased γ-globulin concentration (gammopathies)
(1) Polyclonal gammopathies are present with chronic antigenic stimulation, immune-mediated disease, liver disease, lymphoma, and lymphocytic leukemia
(2) Monoclonal gammopathies are present with multiple myeloma, extramedullary plasmacytoma, lymphoma, lymphocytic leukemia, chronic pyoderma, plasmacytic enterocolitis, canine ehrlichiosis, visceral leishmaniasis (dog), lymphoplasmacytic stomatitis (cats), and idiopathic monoclonal gammopathy
C. Hyperfibrinogenemia occurs in dehydration, inflammation, renal disease, disseminated neoplasia, and during terminal pregnancy in cattle

DETECTION OF MUSCLE INJURY (Figure 1-4)

I. Creatine kinase (CK)
A. Also referred to as creatine phosphokinase
B. Located in the cytoplasm of skeletal muscle, cardiac muscle, and smooth muscle.
1. Considered to be a muscle-specific enzyme even though it is also found in the brain and nerves
2. Increased CK activity has not been observed in injury to the central nervous system
C. May be falsely elevated with hemolysis, hyperbilirubinemia, and muscle fluid contamination of a blood sample during difficult venipuncture
D. Increased CK is caused by skeletal muscle injury, cardiac muscle injury, or with muscle catabolism (especially in cats)
E. The magnitude of the increase in CK does not correlate to the severity of the injury
F. Serum CK rapidly increases after injury and rapidly decreases when the injury ceases (normal within 24 to 48 hours)

II. Aspartate aminotransferase (AST)
A. Previously known as serum glutamic oxaloacetic transaminase (SGOT)
B. Present in cytoplasm and organelles of hepatocytes, skeletal muscle, and cardiac muscle

Dog and Cat
↑ ALT greater than ↑ AST; no ↑ CK → liver injury
↑ AST greater than ↑ ALT; ↑ CK → skeletal muscle injury
Horse and Ruminant
↑ AST; no ↑ CK → liver injury
↑ AST and ↑ CK → skeletal muscle injury or concomitant skeletal muscle injury and liver injury

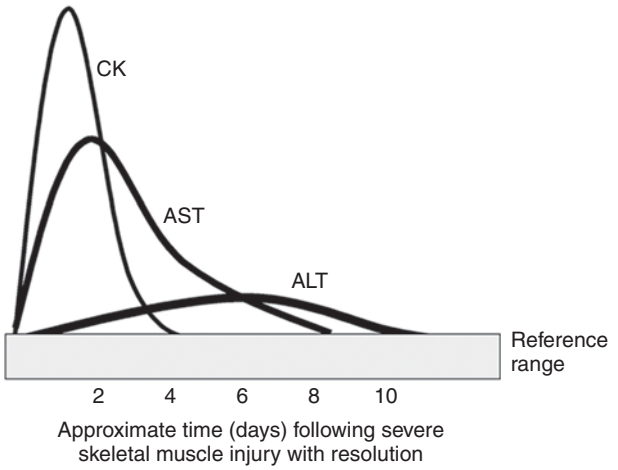


Figure 1-4 The approximated magnitude and duration of increase in CK, AST, and ALT levels in the circulation after severe injury to the skeletal muscle in all domestic species are illustrated. In dogs and cats, the relative magnitude of ALT, AST and CK levels help differentiate predominantly liver or skeletal muscle injury. In horses and ruminants, a rise in the AST level with or without a notable change in the CK level is compatible with liver injury. The AST and CK levels are increased in horses and ruminants with skeletal muscle injury alone or with concomitant liver injury. The latter is indicated by an increase in the sorbitol dehydrogenase or GLD levels. ALT, Alanine aminotransferase; *AST,* aspartate aminotransferase; *CK,* creatine kinase. (From Meyer D, Harvey JW. *Veterinary Laboratory Medicine: Interpretation and Diagnosis, 3rd ed.* St Louis, 2004, Saunders.)

C. Increases more slowly than CK with injury and persists in the serum longer
D. Useful in combination with CK to determine when muscle damage has occurred.

III. ALT
A. Previously known as SGPT
B. Some elevation may be seen in dogs and cats with muscle injury and no hepatic damage
C. Small amounts of activity in skeletal and cardiac muscle but can contribute to elevated ALT because the muscle mass is large

IV. Lactate dehydrogenase (LDH)
A. Located in the cytoplasm in most cells and thus is nonspecific for muscle
B. Five isoenzymes exist, and analysis of isoenzymes may be more beneficial

V. Myoglobin
A. Released from dead muscle cells into the blood (myoglobinemia) and excreted into the urine (myoglobinuria)
B. Myoglobinuria results in a dark brown to red-brown coloration of the urine
C. Myoglobin is rapidly excreted by the kidneys and thus serum remains colorless to yellow
1. If urine is positive for hemoglobin on a dipstick and serum is colorless to yellow, then myoglobinuria is probably present
2. If urine is positive for hemoglobin on a dipstick and serum is red, then hemoglobinuria is probably present
D. Addition of ammonium sulfate to produce an 80% concentration in urine will cause hemoglobin to precipitate. The resultant supernatant will test negative for hemoglobin because the hemoglobin has precipitated. If myoglobinuria is present, the supernatant will continue to test positive for hemoglobin with dipstrip

EVALUATION OF LIPIDS

I. Lipid metabolism
A. Triglyceride
1. Triglycerides are composed of a glycerol backbone to which three fatty acids (of varying length and characteristics) are attached
2. When ingested, triglycerides are broken down to monoglycerides and free fatty acids for absorption by the intestinal mucosal cells. Absorption requires bile acids and micelle formation. Once in the intestinal mucosal cells, triglycerides are formed from the absorbed monoglycerides and free fatty acids
3. Hypertriglyceridemia normally occurs in the postprandial state. Increases in serum triglyceride concentrations are also noted in some primary lipid disorders and in secondary lipid disorders such as pancreatitis, hypothyroidism, diabetes mellitus, nephrotic syndrome, hyperadrenocorticism, and cholestasis
4. Hypercholesterolemia may falsely decrease serum triglyceride measurement
B. Cholesterol
1. Present only in animal tissues
2. Can be produced in almost any tissue in the body, but the major sites of cholesterol synthesis are the liver and small intestine
3. Absorbed by the small intestine; absorption requires bile acids and micelle formation
4. Hypercholesterolemia is noted in primary lipid disorders and also in association with hypothyroidism, diabetes mellitus, nephrotic syndrome, pancreatitis, hyperadrenocorticism, and cholestasis. Cholesterol is elevated normally in the postprandial period
5. Hypertriglyceridemia and hyperbilirubinemia may falsely lower the serum cholesterol concentration
C. LPs are conglomerates of various apoproteins, cholesterol, triglyceride, and phospholipids
1. Metabolism
a. LPs are classified according to their density as chylomicrons: very-low-density lipoproteins (VLDLs), intermediate-density lipoproteins (IDLs), and high-density lipoproteins (HDLs)
b. Chylomicrons are formed primarily by the small intestine and are composed of high quantities of triglyceride, with low

amounts of protein. They are the least dense of the LPs and will 'float' in a serum sample that contains excess chylomicrons (hyperchylomicronemia). Chylomicrons are normally cleared rapidly by the liver after a meal. Lipoprotein lipase is required for proper chylomicron metabolism

c. VLDLs are formed by the liver; they are smaller than chylomicrons and have a higher content of protein and lower triglyceride level. They are heavier than chylomicrons. Once in the circulation, exchanges of proteins and constituents occur between LPs, and IDLs are formed. IDL is rapidly converted to LDL. Lipoprotein lipase activity is required

d. LDLs are heavier and smaller than VLDLs and have a higher protein content and a lower triglyceride content. They are capable of delivering cholesterol to many tissues via the LDL receptor

e. HDLs are formed mostly by the liver and are integral in the return of cholesterol from tissues to the liver (reverse cholesterol transport). HDLs are the heaviest and smallest LPs and have the highest protein and lowest triglyceride content

2. Species differences

a. Most animal species are *HDL mammals*, meaning that most of the cholesterol is carried by HDLs. HDL mammals include dogs, cats, horses, ruminants, rodents, and most other species. Pigs, rabbits, guinea pigs, hamsters, camels, rhinoceros, most monkeys, and humans are *LDL mammals*, meaning that most cholesterol is carried by LDLs

b. In LDL mammals, cholesterol ester transfer protein (CETP) transfers most of the cholesterol from HDLs to LDLs; thus LDL is the major carrier of cholesterol

c. HDL mammals have a low level of CETP, and cholesterol is not transferred to LDLs; thus HDL transports most of the cholesterol

d. Lipoprotein characteristics of most animal species are very different from human LPs

II. Diagnostic approach to hyperlipidemia

A. Serum turbidity

1. Hypertriglyceridemia causes serum turbidity
2. The opacity of the serum correlates to serum triglyceride content. Serum with the appearance of whole milk can have triglyceride concentrations as high as 2500 to 4000 mg/dL

B. Refrigeration test

1. Place the serum sample in the refrigerator overnight
2. Chylomicrons will float, forming a "cream layer"
3. If the serum below the chylomicron layer is still turbid, then other LPs (most likely VLDLs or LDLs) are present in excess

C. Lipoprotein electrophoresis

1. Separates LPs based on their charge and mobility on agarose gel
2. If submitting a serum sample for lipoprotein electrophoresis, make sure the laboratory has experience with animal samples and interpretation of LP patterns; otherwise, erroneous interpretations will occur
3. Most useful for monitoring the effectiveness of treatment of lipid abnormalities

III. Hyperlipidemia

A. Postprandial hyperlipidemia is the most common cause of hyperlipidemia

B. Equine hyperlipidemia

1. Occurs primarily in miniature horses, ponies, and donkeys
2. Caused by starvation and chronic illness, creating a negative energy balance with mobilization of triglycerides

C. Primary hyperlipidemia

1. Idiopathic hypercholesterolemia

a. First observed in briards but has been seen in other breeds as well

b. Marked increase in serum cholesterol with generally normal triglyceride concentrations

c. In dogs, an increase in HDL_1 is noted

2. Idiopathic or primary hyperlipoproteinemia

a. Most likely, many different syndromes can cause idiopathic hyperlipoproteinemia.

b. One variant in dogs has been shown to be due to a decrease in lipoprotein lipase activity

c. A primary hyperlipoproteinemia in lambs is the result of decreased lipoprotein lipase activity

d. Associated with miniature schnauzers but also occurs in many other breeds (especially Shetland sheepdogs)

3. Hyperchylomicronemia of cats

a. Due to a decrease in lipoprotein lipase activity

b. Clinically well characterized; affected cats have xanthomas, nerve dysfunction, lipemia retinalis, and anemia. Extreme elevations of triglyceride and cholesterol have been noted

D. Secondary hyperlipidemia occurs as a result of other disease processes

1. Causes include hypothyroidism, diabetes mellitus, hyperadrenocorticism, pancreatitis, nephrotic syndrome, cholestasis, and the ingestion of diets very high in fat (sled-dog diets)
2. Most of the lipid abnormalities resolve with treatment of the underlying condition

IV. Hypolipidemia

A. May occur with liver failure

B. Decreases in triglyceride may be seen in association with maldigestion and malabsorption syndromes, lymphangiectasia, and portosystemic shunts

EVALUATION OF GLUCOSE METABOLISM

I. Hypoglycemia. Causes include the following:
 A. Starvation or malabsorption; occurs only after long-term starvation
 B. Increased insulin production (insulinoma); reported in dogs, cats, and ferrets
 C. Insulin overdose
 D. Hypoadrenocorticism
 1. Occasionally, a mild hypoglycemia is seen
 2. A result of decreased gluconeogenesis and increased insulin-mediated uptake of glucose by muscle
 E. Growth hormone deficiency
 1. Hypoglycemia is uncommon
 2. Occurs if current hypoadrenocorticism is present
 F. Liver failure
 1. From decreased hepatic gluconeogenesis and glycogenolysis
 2. Occurs after greater than 70% hepatic function has been lost
 G. Portosystemic shunt (if hepatic dysfunction is severe)
 H. Extreme exertion (hunting dogs and horses)
 I. Juvenile hypoglycemia in toy and miniature dogs
 J. Glycogen storage diseases
 K. Sepsis
 1. More common with advanced sepsis
 2. Possibly because of impaired gluconeogenesis and glycogenolysis and increased utilization of glucose by tissues
 L. Ketosis (cattle); negative energy balance leads to hypoglycemia with an increase in ketone bodies production
 M. Pregnancy toxemia (sheep) from negative energy balance
 N. Neonatal hypoglycemia; common in pigs
 O. Neoplasia (other than insulinoma)
 1. Lymphocytic leukemia, lymphoma, leiomyosarcoma, leiomyoma, hepatocellular carcinoma, mammary carcinoma, pulmonary carcinoma, hemangiosarcoma, hepatoma, plasma-cell tumor, malignant melanoma, and salivary adenocarcinoma
 2. May be related to excessive glucose utilization by the tumor or secretion of insulin-like growth factor 1 (IGF-1)

II. Hyperglycemia. Causes include the following:
 A. Diabetes mellitus
 B. Postprandial hyperglycemia (does not occur in ruminants)
 C. Hyperadrenocorticism
 D. Stress (most common cause in cats)
 E. Administration of corticosteroids
 F. Catecholamine release (pain, exertion, excitement, pheochromocytoma)
 G. Tumors (glucagonoma, pituitary tumor secreting excess growth hormone)
 H. Increased progesterone production
 I. Pancreatitis
 J. Pituitary pars intermedia dysfunction (Equine Cushing syndrome)
 K. Drugs (glucocorticoids, progesterone, xylazine, ketamine, morphine, phenothiazine, adrenocorticotrophic hormone, glucose-containing fluids)
 L. Milk fever (cattle)
 M. Neurologic diseases (cattle); from increased glucocorticoid and epinephrine concentrations
 N. Proximal duodenal obstruction (cattle); causes extreme hyperglycemia due to decreased peripheral glucose use
 O. Colic (horses); horses with very high glucose concentrations have a poor prognosis
 P. Hyperthyroidism; occurs in a small percentage of cats and may be due to stress or other causes of hyperglycemia
 Q. Moribund condition (ruminants)

III. Blood glucose analysis
 A. Fast dogs and cats for 12 hours to avoid postprandial hyperglycemia. Do not fast if hypoglycemia is suspected
 B. Horses and cattle are typically not fasted
 C. Separate serum or plasma from cells within 30 minutes of collection. Glycolysis of RBCs will result in a 10% glucose decrease per hour if not separated
 D. Minimize stress and excitement in cats before collecting sample

IV. Urine glucose analysis
 A. Glucose appears in the urine when the renal threshold for glucose has been exceeded
 1. Dogs and cats; approximately 180 to 200 mg/dL
 2. Horses; approximately 180 mg/dL
 3. Cattle; approximately 100 mg/dL
 B. The renal threshold may be decreased with proximal tubular abnormalities, Fanconi syndrome, amyloidosis in dogs, and exposure to nephrotoxins

V. Glucose tolerance test
 A. Useful for detecting decreased glucose tolerance in persistently hyperglycemic animals
 B. Avoid chemical sedation
 C. Methods
 1. Oral
 2. IV; superior to oral method because it is not affected by GI disorders

VI. Serum insulin
 A. Most useful in hypoglycemic animals, especially if the hypoglycemia is sporadic.
 B. Start fasting, and monitor serum glucose until the glucose concentration is below 60 mg/dL. Collect sample for insulin measurement at this time
 C. If insulin concentration is in the middle part of the reference range or above in the presence of hypoglycemia, an insulinoma is suspected
 D. In horses, an elevated serum insulin concentration with a normal to slightly increased serum glucose concentration is suggestive of metabolic syndrome and insulin resistance

VII. Fructosamine
 A. Reflects blood glucose over previous 5 to 8 days
 B. Hypoproteinemia decreases and hyperproteinemia increases fructosamine concentration

C. Cannot detect hypoglycemic periods; the Somogyi effect will look like poor control with fructosamine measurement
D. Can be used for an indication of overall control of diabetes if cannot obtain a glucose curve

VIII. Glycated hemoglobin
A. Reflects blood glucose over the lifespan of the RBC
1. 8 to 12 weeks in dogs
2. 5 to 6 weeks in cats
B. Anemia falsely lowers glycated hemoglobin, and polycythemia will increase measurement
C. Measure at a veterinary laboratory

EVALUATION OF LABORATORY DATA

I. Establishment of reference ranges
A. The term *normal range* should be discarded
B. A reference range for a particular test is derived from the results from a group fitting a stated description or selection criteria. Individuals are selected from a parent population using defined criteria and are then tested
C. Establishment of the mean ± two standard deviations will provide a range in which 95% of the population should be included. About 2.5% of the population will have values below and 2.5% of the population will have values above this range
D. Establishment of the mean ± three standard deviations will provide a range in which 99% of the population should be included. About 0.5% of the population will have values below and 0.5% of the population will have values above this range. Although this range will include a higher percentage of individuals, it is often a very broad range with a higher likelihood of overlap with an affected population. Therefore most reference ranges are established using the mean ± two standard deviations

II. Diagnostic performance of tests
A. Sensitivity
1. *Sensitivity* is defined as the ability to predict the presence of disease or the fraction of those with a specific disease that the assay accurately predicts
2. It is calculated by dividing the number of true positives (TP) by the total of those with disease (the TP plus the false negatives [FN]); TP/(TP + FN) * 100
3. Think of sensitivity as the ability to find positives. If a test has very high sensitivity, all the positives have been found (even if the test identifies some without disease as positive). Those that then test negative have a very high likelihood of being truly negative. Thus, if the sensitivity of an assay is high, then the diagnosis of the negative state can be highly trusted
4. Think of sensitivity in terms of the disease state first. Sensitivity is an indicator of those with disease who also test positive

B. Specificity
1. *Specificity* is defined as the ability to predict the absence of disease, or the fraction of those without disease that the assay correctly predicts
2. It is calculated by dividing the number of true negative (TN) by the total of those without disease (the TN plus the false positives [FP]); TN/(FP + TN) * 100
3. Think of specificity as the ability to find negatives. If a test has a very high specificity, all the negatives have been found (even if the test identifies some with disease as being negative). Thus, if the specificity of an assay is high, then the diagnosis of the positive state can be highly trusted
4. Think of specificity in terms of the disease state first. Specificity is an indicator of those without disease who also test negative

C. Positive predictive value (PPV)
1. PPV is the percent of patients with positive test results who actually have the disease
2. PPV is calculated by dividing the number of TP by the total of those who tested positive (the TP plus the FP); TP/(TP + FP) * 100
3. PPV is influenced by the prevalence of the disease in the population; it increases as the prevalence increases
4. Think of PPV in terms of the test result first. PPV is an indicator of those who test positive and also have disease

D. Negative predictive value (NPV)
1. NPV is the percent of patients with a negative test result who do not have the disease
2. NPV is calculated by dividing the number of TP by the total of those who tested negative (the true negatives plus the false negatives); TN/(TN + FN) * 100
3. NPV is influenced by the prevalence of the disease in the population; it decreases as the prevalence increases
4. Think of NPV in terms of the test result first. NPV is an indicator of those who test negative and also happen to be without disease

E. Positive diagnostic likelihood ratio (PDLR)
1. PDLR is the probability of a positive test result in those with disease divided by the probability of a positive test result in those without disease
2. PDLR = sensitivity/(1-specificity)
3. A higher number indicates a higher probability of being correct with a positive diagnosis
4. PDLR is not influenced by the prevalence of the disease in the population

F. Negative diagnostic likelihood ratio (NDLR)
1. NDLR is the probability of a negative test result in those with disease divided by the probability of a negative test result in those without disease

2. NDLR = [FN/(FN + TP)]/specificity
3. A lower number indicates a higher probability of being correct with a negative diagnosis
4. NDLR is not influenced by the prevalence of the disease in the population

G. Diagnostic discordance
1. Diagnostic discordance gives an estimate of the overall rate of an incorrect diagnosis
2. Diagnostic discordance in the number of samples with diagnostic disagreement divided by the total number of samples

Supplemental Reading

DiBartola S, *Fluid Therapy in Small Animal Practice,* 3rd ed. St Louis, 2006, Saunders.

Kaneko JJ, Harvey JW, Bruss ML, eds. *Clinical Biochemistry of Domestic Animals*, 5th ed. San Diego, 1997, Academic Press.

Thrall MA, ed. *Veterinary Hematology and Clinical Chemistry*. Philadelphia, 2004, Lippincott Williams & Wilkins.

Villiers E, Blackwood L. *BSAVA Manual of Canine and Feline Clinical Pathology*. Gloucester, UK, 2005, BSAVA.

Willard MD, Tvedten H. *Small Animal Clinical Diagnosis by Laboratory Methods.* St Louis, 2003, Saunders.

Clinical Pathology: Cytology

2 CHAPTER

Craig A. Thompson

Cytology is a powerful, yet limited, morphologic tool that can be used for the diagnosis and monitoring of disease in essentially every species of animals. Its application is limited only by the imagination of the clinician obtaining the sample and the skill and experience of the cytologist. Samples can be obtained from numerous locations, including the skin, liver, bone, gastrointestinal (GI) tract, lungs, and even the central nervous system (CNS). Likewise, lesions that have been investigated using cytology include masses, effusions, exudates, ulcerations, ultrasonographic and radiographic lesions, as well as lesions that can be seen and obtained only using computed tomography (CT) guidance. Direct smears, impressions, concentrations, and cytocentrifuge preparations are just a few of the methods for getting the sample onto a slide for examination. This review is not meant to be an exhaustive exploration of every system, organ, and type of disease that is amenable to cytology; rather, it is designed to cover the basics of cytology that any graduating veterinary student should comprehend and therefore be prepared for the North American Veterinary Licensing Examination (NAVLE).

I. Comparison and contrast of cytology and biopsy with histologic examination
 A. Benefits of cytology over histology
 1. Speed. A cytologic specimen can be obtained, stained, and evaluated in minutes rather than the many hours to days that are required for fixation, processing, staining, and evaluation for traditional histology (excluding frozen sections, which are uncommon in veterinary medicine)
 2. Affordability
 a. A needle, collection tube, slide, and stain generally cost fractions of a dollar for cytology
 b. A biopsy instrument, formalin, tissue processing, and staining cost considerably more for histology
 3. Invasiveness
 a. Obtaining cells from an animal, whether by fine needle aspiration or impression of a draining tract, is nearly always less traumatic and induces less morbidity
 b. Obtaining a tissue specimen by incisional or excisional biopsy is more likely to require sedation or general anesthesia; induces more trauma; and carries a higher risk of hemorrhage, morbidity, and mortality
 4. Detail. Oil immersion lenses are readily available and can be used in the evaluation of cytologic specimens, which allow for detection of fine details such as chromatin patterns, nucleolar features, and minute organisms
 5. Fluids. Histology is not generally applicable to fluid evaluation, such as serous cavity effusions, cerebrospinal fluid, and synovial fluid
 B. Benefits of histology over cytology
 1. Architecture. Cytologic examination provides an excellent evaluation of the cell populations, their morphology, and the background in which they lie. Histology affords a glimpse of the tissue as it was in situ, which includes important features such as invasion (vascular and/or basement membranes) and spatial arrangement of cells in relation to other features, such as inflammation
 2. Volume. For the most part, the volume of the sample obtained from comparable locations for histologic evaluation is appreciably greater compared with cytology
 3. Durability. For samples obtained from similar sites, fixed tissues will last longer and can be manipulated more readliy than cytologic specimens
 a. Paraffin-embedded tissues are essentially inert except in temperature extremes
 b. Cytologic specimens will degrade over time unless coverslipped and kept in a dark, dry place
 c. If additional stains are needed later, more sections can be cut from the paraffin blocks, whereas cytologic specimens have to be destained and re-stained
II. Stains commonly used for cytology
 A. Gram stain
 1. Used to classify bacteria
 2. Gram-positive (G+) bacteria have teichoic acid in their cell walls and stain deep blue
 3. Gram-negative (G−) bacteria have lipopolysaccharides in their cell wall and are either unstained or take on the counterstain (safranin or fuchsin), which is generally red
 B. Romanowsky type
 1. For use on air-dried specimens
 2. Aqueous-based stains
 3. Includes a number of stains: Wright's, Giemsa, Wright's Giemsa and May-Grünwald-Giemsa,

Leishman's, Diff-Quik (Harleco, Gibbstown, NJ) and DipStat (Medichem, Inc., Santa Monica, CA)
4. Frequently used as a mainstay in cytopathology because they impart different colors to cytoplasm and the nucleus (i.e., polychromatic stains), allowing good visualization of each

C. New methylene blue
1. An aqueous stain; therefore, can be used to visualize some lipids
2. Poor cytoplasmic detail with excellent nuclear and nucleolar visualization
3. Good for detection of nucleated cells, all bacteria, fungi, and yeast
4. Because erythrocytes stain poorly, it can be used to evaluate nucleated cell populations when heavy blood contamination is present
5. Also frequently used as a stain for urine sediment (Sedi-Stain)
6. Used in hematologic specimens to enumerate reticulocytes and identify some organisms

D. Papanicolaou stain
1. Similar to hematoxylin and eosin (H&E), bichrome, trichrome, and Sano's modified stain
2. Provide excellent nuclear details and delicate cytoplasmic details
3. Allow visualization of cells in clumps and layers
4. Laborious methods and availability limit its usefulness in veterinary medicine

E. Prussian blue
1. Stains ferric (Fe^{3+}) iron
2. Detects loosely bound iron such as that in hemosiderin
3. Will not identify iron tightly bound, such as with hemoglobin
4. Does not stain hematoidin

F. Fat stains
1. Oil-Red-O (ORO) can be used on fresh, non–alcohol-fixed smears to identify fat
2. Sudan Black B (SBB) stains fat a blue-black color

G. Immunocytochemical stains
1. Use antibodies against epitopes, such as clusters of differentiation (CD antigens) to identify the cell line of origin of unknown cells
2. Can be very specific and powerful
3. Limited only by the antibodies available, many of which are conserved across species, therefore allowing the use of human antibodies
4. Similar technology is used for flow cytometry, but using a fluid medium (e.g., effusions)

INFLAMMATION

The *first* thing *any* diagnostic sample should be evaluated for is inflammation. Without the benefit of architecture, the relationship of the inflammatory cells with the noninflammatory cells is unknown. Inflammation can induce a variety of hyperplastic, dysplastic, and metaplastic changes in the noninflammatory components of a smear. These changes could be misinterpreted as neoplastic changes (see criteria of malignancy). The type of inflammation present can help shape a differential diagnosis list, especially when combined with other clinical data. By ruling out inflammation, the background, other populations present, and their morphologies can then be evaluated with confidence that the changes seen are a spontaneous change and not induced by the inflammation.

I. Types of inflammatory cells and their morphology

A. Neutrophils
1. 13 to 16 μm in diameter
2. Three to five nuclear lobes connected by thin intranuclear bridges
3. Female animals occasionally have a Barr body, often described as a small drumstick on the end of one nuclear lobe
4. The cytoplasm is clear (dogs, cats, horses) to pink (ruminants)

B. Macrophages
1. Medium- to large-sized cells, often greater than 25 μm
2. Nuclei can range in shape from round to markedly pleomorphic
3. Can take on different morphologies
 a. Mononuclear, variably vacuolated cell
 b. Epithelioid macrophages: Smooth blue cytoplasm with eccentrically placed nucleus
 c. Multinucleated giant cell

C. Eosinophils
1. 13 to 16 μm in diameter
2. Three to five nuclear lobes connected by thin intranuclear bridges
3. Variable numbers of granules. Vivid pink, discrete and round to rod-shaped, pink granules (Feline)

D. Lymphocytes
1. 7 to 13 μm in diameter
2. Single round nucleus
3. Uniformly high nucleus-to-cytoplasm (N:C) ratio

E. Plasma cells
1. 9-15 μm long
2. Ovoid shaped
3. Eccentrically placed nucleus
4. Dark blue cytoplasm due to the abundant amount of rough endoplasmic reticulum (RER)
5. Variably sized perinuclear pale to clear zone
6. Mott cells are plasma cells that are congested with immunoglobulin, contained within pale blue Russell bodies

II. Suppurative-neutrophilic-purulent inflammation

A. Denotes a population that is more than 85% neutrophils
1. Suggests an active, *likely* (but not necessarily) acute process; however, can be a chronic process
2. Often seen with infectious etiologies (bacteria mainly; fungal and viral also)
3. Also seen with traumatic, toxic insults, immune-mediated diseases, and neoplastic processes, among others
4. Neutrophils *are not* normal tissue residents; they have been called there for some reason

B. Degenerate changes
1. Represented by a set of morphologic changes that are primarily nuclear

2. Occur when the neutrophils are exposed to a toxic environment and *killed* rather than allowed to age and become apoptotic
3. Karyolysis
 a. Indicates rapid cell killing and is an unmistakable sign of degeneration
 b. Often seen with bacterial infections, especially gram-negative (G−), when endotoxin is present
 c. Swelling of the nuclear lobules and intranuclear bridges
 d. Loss of nuclear staining intensity
 e. Loss of intranuclear connections
 f. Loss of chromatin clumping
 g. Decrease in the density of chromacenters
 h. Nuclear margin becomes indistinct
 i. Cytoplasmic margin *is still intact*
4. Pyknosis
 a. Usually indicates a slow change in a relatively benign, perhaps mildly toxic environment
 b. May represent old age changes or apoptosis due to low-grade insult
 c. Condensation and coalescing of the nucleus into a single dark, hyperchromic structure
 d. The cytoplasm of the cell also frequently condenses and darkens
 e. Commonly seen in fluids
5. Karyorrhexis
 a. Generally means similar things as pyknosis and fragmentation
 b. Pyknosis of neutrophil nuclear lobes
 c. Commonly seen in fluids

III. Eosinophilic inflammation
 A. Commonly present in addition to another type of inflammation
 B. Indicated when eosinophils are present as greater than 10% of the overall population of inflammatory cells
 1. Allergy and hypersensitivity reactions
 a. Eosinophilic plaques
 b. Rodent ulcers
 c. Pulmonary infiltrates of eosinophils (PIE)
 2. Parasitic infestation
 a. Heartworm disease
 b. Aberrant migration of parasites
 (1) *Dirofilaria immitis* microfilaria tissue migration in felines
 (2) Feline ischemic encephalopathy (FIE) and *Cuterebra* spp. larval migration
 c. Flea-bite allergy
 3. Fungal infection
 a. *Cryptococcus neoformans* in the CNS
 4. Neoplasia
 a. Mast cell tumor
 b. Lymphoma

IV. Macrophagic inflammation
 A. Composed primarily of mononuclear, variably vacuolated macrophages
 1. Increased vacuolation tends to indicate increased amount of activation
 2. Macrophages can contain a variety of phagocytized material, including other cells (e.g., apoptotic or senescent cells)
 B. Indicates chronic inflammation
 1. Foreign bodies
 2. Fungal infection
 a. *Blastomyces dermatitidis*
 b. *Histoplasma capsulatum*
 c. *Coccidioides immitis*
 d. *Cryptococcus* spp.
 3. Some metazoan infestations
 4. "Higher bacteria" infections
 a. *Nocardia* spp.
 b. *Actinomyces* spp.
 c. *Mycobacterium* spp.
 C. Pure macrophagic inflammation is more common in ruminants, reptiles and avian

V. Granulomatous inflammation
 A. Etiology and differential diagnoses similar to macrophagic
 B. Mixed cell population
 1. Variably vacuolated mononuclear macrophages
 2. Epithelioid macrophages have a single, eccentrically placed nucleus set in a moderate amount of smooth blue cytoplasm
 3. Multinucleate or polykaryotic giant cells that have two or more (more than 20 possible) nuclei
 4. Not uncommon to see lymphocytes, plasma cells, and fibroblasts present as well

VI. Pyogranulomatous inflammation
 A. Granulomatous inflammation with the addition of neutrophils
 B. Differential diagnoses are identical to granulomatous inflammation

VII. Lymphocytic and/or plasmacytic
 A. Seen with a variety of causes
 1. Allergic reactions, such as vaccination sites
 2. Associated with viral infections
 3. Can also be associated with chronic inflammation
 4. Associated with nonspecific antigenic stimulation, such as with inflammatory bowel disease (IBD)
 B. Mixed cell population
 1. Lymphocytes are a mixture of small-, intermediate-, and large-sized cells
 2. Plasma cells

VIII. Hemorrhage. Not a type of inflammation; however, commonly seen with it
 A. Peracute: Indistinguishable from blood contamination
 1. Platelets present
 2. Leukocyte numbers and morphology identical to that of the peripheral circulation
 3. Packed cell volume (PCV) of fluid similar to peripheral blood
 B. Acute or active: Generally, changes occur in a matter of hours. Erythrophagia or erythrophagocytosis by macrophages
 C. Chronic
 1. Production of hemosiderin by macrophages as erythrocytes are broken down. Appears as a amorphous, puffy gray-black pigment that stains positive with Prussian blue

2. If in an anaerobic environment, hematoidin may be produced. Appears as a translucent, yellow, rhomboid-shaped crystal that is occasionally amorphous in shape

NEOPLASIA OR HYPERPLASIA

Once an inflammatory process is ruled out, morphologic deviations from the remaining cell's normal morphology are assumed *not* to be due to metaplasia or dysplasia associated with inflammation. The next step in interpreting the remaining cells is to determine what broad category of cells they fall into and then to determine whether they represent a benign population (e.g., hyperplasia, benign neoplasia) or a malignant population.

I. Four primary cell and tissue types
 A. Mesenchymal: Examples include fibroblasts, osteoblasts, chondroblasts
 1. Generally exfoliate poorly, relative to the technique used
 2. Are often small- to medium-sized cells
 3. Vary in shape, including ovoid, stellate, fusiform, spindled, elongate
 4. Can and will form disorganized clumps; however, *never* organized, cohesive sheets
 5. Occasionally associated with acellular pink matrix (e.g., osteoid, chondroid, collagen, etc.) that they are producing
 6. The criteria of malignancy can be applied to determine cellular disposition (i.e., benign vs. malignant)
 B. Epithelial: Examples include squamous cells, salivary epithelium, GI mucosa, hepatocytes, renal tubular cells
 1. Generally exfoliate quite well, regardless of the technique used
 2. Are often medium- to large-sized cells
 3. Vary in shape and are often round, angular, caudate to polygonal; however, they *can* be spindle shaped
 4. Can and will form organized, cohesive sheets as well as disorganized clumps
 5. Glandular epithelium will occasionally be seen in an acinar or rosette arrangement
 6. The criteria of malignancy can be applied to determine cellular disposition
 C. Round or discrete: Limited to a few specific types
 1. Cytologic features of the overall cell type
 a. Generally exfoliate extremely well regardless of the technique used
 b. Are often small- to somewhat medium-sized cells
 c. Primarily have a round nucleus with round cell shape
 d. Dense preparations can have the appearance of a confluent cluster; however, they *never* form organized, cohesive sheets
 2. Lymphocytes
 a. Small size, generally round
 b. Round nuclei
 c. Uniformly high N:C ratio
 d. Nuclei generally display a finely stippled chromatin pattern
 e. Immature cells are larger and have an open, less intensely staining chromatin pattern, with lymphoblasts having nucleoli
 f. Regardless of location (i.e., lymph node, spleen, gut wall, spinal cord mass, etc.), the main feature used to determine malignancy is the *population* of lymphocytes
 g. The closer the population is to being pure (primarily immature), the more likely they are malignant
 h. Small cell lymphoma is very difficult, if not impossible, to diagnose cytologically
 i. Interpretation can be extremely difficult without tissue architecture; therefore, any uncertainty (i.e., mismatch of cytologic and clinical findings) warrants biopsy with histologic evaluation
 3. Transmissible venereal tumor (TVT)
 a. Canine only; often on prepuce, vulva, or nose; however, rare cases are disseminated
 b. Nuclei have clumped chromatin and often one or two prominent nucleoli
 c. Cells have moderate amounts of pale blue cytoplasm with distinct, peripherally located, punctate vacuoles
 d. Many mitotic figures are often seen
 e. Criteria of malignancy do not apply once identity is established
 4. Plasma cells
 a. Generally round to ovoid shaped
 b. Nucleus often has coarsely clumped chromatin that has been described as "clock-faced" in histologic preparations
 c. Nucleus often eccentrically placed in a moderate amount of dark, royal blue cytoplasm
 d. Cells almost always have a distinct, prominent, pale-staining, perinuclear clearing area that represents the Golgi zone, which is prominent because of profound protein (immunoglobulin) production
 e. Although the criteria of malignancy can be rather marked, plasmacytomas often behave biologically benign
 5. Benign cutaneous histiocytoma
 a. Canine only, common in young animals
 b. Medium-sized round cells
 c. Nuclei have a fine chromatin pattern, show moderate pleomorphism, and are generally set in a moderate amount of pale-staining cytoplasm with distinct margins
 d. Often have pale cytoplasm that is so pale that only a halo around the nucleus is seen
 e. The cells are otherwise rather monotonous
 f. The presence of a population of small lymphocytes in addition to the histiocytoma cells indicates the imminent, spontaneous regression of the tumor, which is expected
 6. Mast cell tumor (MCT)
 a. Well-differentiated mast cells have abundant, small, dark purple granules that often obscure the round nucleus

b. Diagnosis is based on the finding of large aggregates of mast cells; however, the criteria of malignancy can be applied to identify poorly differentiated from well-differentiated tumors
c. Grading (i.e., grades I, II, III) is exclusively a histologic feature
d. The metachromatic granules of mast cells will occasionally stain poorly with aqueous stains such as Diff-Quik, necessitating the use of stains such as Toluidine blue or Giemsa how moderate pleomorphism
e. The cells are otherwise rather monotonous
f. Eosinophilic inflammation is not uncommonly seen

D. Naked nuclei-neuroendocrine
1. Class of cells and tissue that presents very similarly for all members
a. Adrenal gland
b. β cells of the pancreas
c. Thyroid epithelium
d. Cells from a chemodectoma
2. The consistent pattern seen is numerous round, bare nuclei closely associated with one another in a background of cytoplasm, with rare intact cells
3. Rare intact cells show pale cytoplasm with indistinct margins
4. Cytologic variation between normal and malignant tissue is often minimal; thus, the ultimate interpretation may lie with the cytomorphology of the cells in conjunction with the clinical findings
5. Some thyroid cells will contain tyrosine granules or be arranged into follicles with or without pink, wispy colloid in the center

II. Criteria for Malignancy

Once inflammation is ruled out, a population of cells can be evaluated morphologically to determine its likelihood of being from a malignant lesion. Three strong criteria of malignancy should be identified. Nuclear (and nucleolar) characteristics carry more weight than cellular.

A. Nuclear
1. Anisokaryosis: Variability in the size of the nuclei
2. Nuclear pleomorphism: Any variation from the shape of nucleus expected for a tissue or type of cell
3. Multiplicity: Multiple numbers of nuclei present within the same cell. Odd numbers of nuclei are especially bad
4. Coarse or atypical chromatin pattern
5. Nuclear molding: The deformation of one nucleus by another nucleus or cell pressing against it

B. Nucleolar
1. Multiplicity: Having more than the expected number of nucleoli. Some cells (e.g., hepatocytes, neurons) generally with have a single, round prominent nucleolus
2. Pleomorphism: Especially angular, elongate, and polygonal forms
3. Variable size

C. Cellular
1. Pleomorphism
2. Anisocytosis: Different sized cells
3. Abnormal granules or vacuoles
4. Number: Very subjective; however, whether the cells have exfoliated, especially whether easily or with difficulty, can be useful information
5. Mitotic figures: Abnormally high numbers or presence of bizarre ones
6. N:C ratios: Variability, especially when high, except for those tissues in which this finding is expected (e.g., lymphocytes, basal cells)

INFECTIOUS AGENTS

Although often associated with inflammation, it is important for any practicing veterinarian to be able to identify infectious agents. These agents can provide a quick diagnosis that allows rapid institution of therapy, long before culture results would be available.

I. Bacteria
A. A vast majority of bacterial species cannot be confidently identified based on morphology alone; however, using a Gram stain, an idea can be obtained and empirical therapy started
B. *Dermatophilus congolensis*
1. Gram-positive filamentous rods
2. Form septa in transverse and horizontal planes, producing a classic "railroad track" appearance

II. Fungi (key morphologic features are bold-faced)
A. *Histoplasma capsulatum*
1. Often found within macrophages
2. 2 to 4 μm in diameter
3. Round with a thin, nonstaining wall
4. Seen in the middle third of the country
B. *Blastomyces dermatitidis*
1. Round
2. Thick, blue wall with broad-based budding
3. 5 to 40 μm in diameter
4. Often prolific within a lesion
5. Seen in the southeast fourth of the contiguous United States
C. *Cryptococcus* spp.
1. Round yeast with a thick wall
2. 2 to 20 μm in diameter
3. Narrow-based budding
4. Often the yeast is surrounded by a thick, nonstaining (with routine stains) capsule that can be nearly imperceptible; up to more than 50 μm thick
D. *Coccidioides immitis*
1. Round
2. Thick blue wall that is described as double refractile on close examination
3. 10 to 100 μm in diameter
4. Occasionally contain 2 to 5 μm endospores
5. Associated with the desert Southwest
6. Often difficult to find within a lesion
7. Often mistaken for *Blastomyces dematitidis*
a. *Coccidioides immitis* can be much larger
b. *Coccidioides* spp. have a double refractile wall

 c. *Blastomyces* spp. will bud, whereas *Coccidioides immitis* endosporulates

E. *Sporothrix schenckii*
 1. Round to ovoid; often described as football shaped
 2. 2 to 3 μm in diameter or length
 3. Zoonotic potential
 4. Often mistaken for *Histoplasma* spp.
 a. *Sporothrix* spp. are generally oblong vs. the round shape of *Histoplasma* spp.
 b. *Sporothrix* spp. organisms are generally slightly smaller
 c. *Sporothrix* spp. infections are nearly always associated with skin and mucosal membranes, not systemic

F. *Candida albicans*
 1. Round to ovoid
 2. 2 to 3 μm in diameter
 3. Occasionally form pseudohyphae that *do not branch*

G. *Aspergillus* spp.
 1. 3 to 6 μm wide, septate hyphae
 2. Dichotomous branching
 3. Diagnosis often presumptive based on morphology in addition to other clinical signs until culture available

Supplemental Reading

Baker R, Lumsden JH. *Color Atlas of Cytology of the Dog and Cat*. St Louis, 2000, Mosby.

Campbell TW, Ellis CK. *Avian and Exotic Animal Hematology and Cytology*, 3rd ed. Ames, Iowa, 2007, Wiley-Blackwell.

Cowell RL, Tyler RD. *Diagnostic Cytology and Hematology of the Horse*, 2nd ed. St Louis, 2002, Mosby.

Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St Louis, 2008, Mosby.

Raskin RE, Meyer DJ. *Atlas of Canine and Feline Cytology*. Philadelphia, 2001, Saunders.

Clinical Pathology: Hematology

3 CHAPTER

Patricia A. Schenck

COMPLETE BLOOD COUNT (REQUIRES SAMPLE COLLECTED INTO AN EDTA TUBE)

I. Packed cell volume (PCV)
 A. Percentage of whole blood composed of red blood cells (RBCs)
 B. Collect in microhematocrit tube and centrifuge in a microhematocrit centrifuge. Three layers will be formed:
 1. Plasma column at the top
 2. Erythrocytes at the bottom
 3. Buffy-coat layer in between the plasma and erythrocytes. The buffy coat layer is a small white band containing leukocytes and platelets. It may be red if many nucleated RBCs are present

II. RBC count is performed by instruments designed for particle counting. It generally parallels the PCV and hemoglobin concentration

III. Plasma protein concentration is determined by refractometry typically. Hyperlipemia can falsely increase the plasma protein concentration by 2 g/dL

IV. Total leukocyte concentration
 A. Done by either Unopette dilution or by instruments designed for particle counting
 B. Both methods detect all nuclei in solution; thus nucleated RBCs will be included in this count

V. Hemoglobin concentration is an index of the RBC mass per unit volume of blood
 A. Provides information similar to that of PCV
 B. In most species (other than the camel family), hemoglobin concentration is about a third of the PCV

VI. Mean cell volume (MCV) reflects RBC size
 A. Macrocytic suggests increased red cell turnover. Some toy poodles, miniature poodles, and greyhounds normally have macrocytic RBCs
 B. Microcytic suggests defective red cell growth. Akita and Shiba Inu dogs normally have microcytic RBCs
 C. *Normocytic* means red cell size is unchanged
 D. Comparing most species, dogs have the highest MCV values (largest RBCs), whereas sheep, llamas, and goats have the lowest MCV values (smallest RBCs)

VII. Mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) help classify anemia

VIII. Red cell distribution width (RDW) describes the relative width of the size distribution curve of the RBCs

IX. Platelet concentration
 A. In most species, platelets are much smaller than RBCs
 B. In cats, platelet volume is about twice that of most other species. Macroplatelets are also common in cats with hematology disorders and may be counted as RBCs with particle-size analyzers

X. Blood smear
 A. The counting area is the small area between the feathered edge and the thick portion of the smear. The feathered edge should be observed for platelet clumps, large cells, and microfilaria
 B. Reticulocyte count evaluates regeneration. A reticulocyte count should be performed if the PCV is below 30% in dogs or below 20% in cats
 1. Reticulocytes are evaluated with methylene blue staining
 2. A corrected percentage for a reticulocyte value greater than 1% or a count of greater than 60,000 cells/μL indicates RBC regeneration. Regeneration takes at least 3 days before reticulocytes appear in the circulation
 3. Horses do not release reticulocytes
 C. Morphology of RBCs
 1. Changes in size
 a. Anisocytosis is variation in RBC size
 b. Microcytic RBCs are smaller than normal RBCs, with a decreased MCV
 c. Macrocytic RBCs are larger than normal RBCs, with an increased MCV
 2. Changes in shape (*poikilocytosis*)
 a. *Poikilocytes* are abnormally shaped RBCs
 b. *Schistocytes* are RBC fragments usually caused by intravascular trauma (i.e., DIC). When two or more spicules are present, the cells are called *keratocytes*
 c. *Acanthocytes (*spur cells) are irregular, spiculated RBCs with unevenly distributed surface projections (Figure 3-1)
 (1) May result from changes in cholesterol or phospholipid concentrations in the RBC membrane
 (2) Acanthocytes are commonly seen in cats with hepatic lipidosis and dogs with hemangiosarcoma

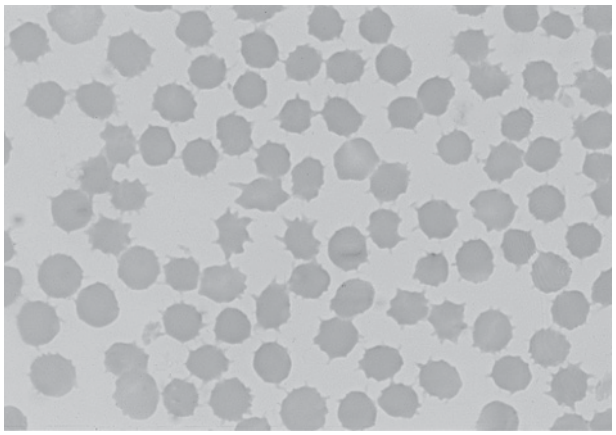


Figure 3-1 Acanthocytes demonstrating irregularly sized spicules in a blood smear from a dog with cholestatic liver disease. Wright's stain, original magnification 132×. (From Cowell RL et al. *Diagnostic Cytology and Hematology of the Dog and Cat,* 3rd ed. St Louis, 2007, Mosby.)

d. *Echinocytes* (burr cells) are spiculated RBCs with evenly distributed blunt to sharp surface projections
 (1) May be artifactual from slow drying of blood smear
 (2) Have been observed in renal disease, lymphoma, rattlesnake envenomation, and chemotherapy. Also observed after exercise in horses
e. *Spherocytes* are dark-staining RBCs that lack central pallor. They are easiest to detect in the dog because dog RBCs have the most central pallor normally. Their presence suggests immune mediated hemolytic anemia
f. *Eccentrocytes* are characterized by a shifting of the hemoglobin concentration to one side, resulting in a loss of central pallor with a clear eccentric zone. They are associated with oxidative damage and may occur in conjunction with Heinz bodies
g. *Leptocytes* are RBCs in which there is excess membrane relative to internal contents. These may occur in vitro when cells contact excess EDTA. Membrane folding causes target cell formation (codocytes)
h. *Codocytes* are thin and bowl-shaped with a dense central area of hemoglobin (the appearance of a target). They may be seen in animals with increased serum cholesterol concentrations but have little significance
i. *Stomatocytes* are RBCs with a mouthlike clear area in the center of the cell. Found in dogs with hereditary stomatocytosis

3. Changes in color
 a. Polychromasia indicates the presence of young erythrocytes, polychromatophilic cells characterized by being larger and slightly bluer than mature RBCs. The degree of polychromasia correlates to the reticulocyte response
 b. Hypochromic RBCs are pale and have a decreased hemoglobin concentration, usually from iron deficiency
4. Structures in or on RBCs
 a. Heinz bodies are caused by oxidant damage to RBCs, with denaturation of hemoglobin. Heinz bodies appear as small, pale structures near the margin of the RBCs, which may protrude. With methylene blue staining, these appear blue
 b. Basophilic stippling is caused by aggregation of ribosomes into small granules. It is associated with immature RBCs in ruminants. Lead poisoning often causes basophilic stippling
 c. Nucleated RBCs are RBCs in the peripheral circulation that have retained their nucleus. They are an indication of regenerative anemia, a nonfunctioning spleen, or steroids (endogenous or exogenous)
 d. Howell-Jolly bodies are nuclear remnants in RBCs that appear as dark staining, round inclusions. They are associated with regenerative anemia or suppressed splenic function
 e. Siderotic granules are visible iron granules in RBCs (siderocytes). They are associated with chloramphenicol, myelodysplasia, and impaired heme synthesis
 f. Viral inclusions are rarely seen but may be seen in canine distemper. They are most commonly found in polychromatic RBCs
 g. Parasites (see later)
5. *Rouleaux formation* is the stacking of RBCs. This is normal in horses and is enhanced when plasma protein concentration is increased (Figure 3-2)
6. Agglutination results in clumps of RBCs and is associated with immune-mediated hemolytic anemia (see Figure 3-2)

D. Leukocytes
 1. Neutrophils
 a. Neutrophils have small granules in the cytoplasm that stain differently, depending on species. In cows, these granules stain faintly pink, giving the cytoplasm a pink tint
 b. Neutrophils are important in an inflammatory response with chemoattraction to the site of inflammation and phagocytosis of organisms or foreign material

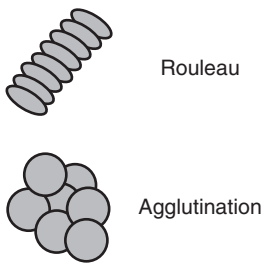


Figure 3-2 The pattern of erythrocyte adhesion that occurs with rouleau is compared with the pattern that occurs with agglutination. (From Meyer D, Harvey JW. *Veterinary Laboratory Medicine: Interpretation and Diagnosis,* 3rd ed. St Louis, 2004, Saunders.)

c. Metamyelocytes are not normally present in peripheral blood. They have a bean-shaped nucleus
d. Band cells may be present normally in small numbers. They have a characteristic horseshoe-shaped nucleus
e. Segmented (mature) neutrophils normally predominate in peripheral blood

2. Lymphocytes
a. Responsible for humoral immunity, cell-mediated immunity, and cytokine responses
b. Round to oval nucleus with minimal clear cytoplasm
c. Normal lymphocytes have smaller diameter than neutrophils. In ruminants, lymphocytes are more irregular in size and may be the same size as neutrophils
d. Reactive lymphocytes are probably B lymphocytes producing immunoglobulin. They have a basophilic cytoplasm with irregular nuclear shape. Nucleus may be indented, giving it a bean-appearance
e. Granular lymphocytes may be natural killer or T cells and contain a small number of pink-purple granules. More prominent in ruminant blood

3. Monocytes
a. Participate in the inflammatory response. Monocytes migrate into tissues and develop into macrophages
b. Commonly misidentified on a blood smear
c. Nucleus may be oval, bean-shaped, or segmented
d. Larger diameter and grayer coloration to the cytoplasm than neutrophils. Cytoplasm may contain fine light purple granules

4. Eosinophils
a. Function not well understood. Contain proteins that bind to parasite membranes and are also involved in allergic responses
b. Vary in morphology among species. All have prominent red to orange cytoplasmic granules. Granules are rod- or barrel-shaped in cat eosinophils. Granules may wash out during staining, leaving empty vacuoles; this is most commonly seen in greyhounds

5. Basophils
a. Function is unknown. Basophils contain histamine and heparin, and their membrane has bound IgE
b. Normally not found on a blood smear
c. Larger than neutrophils, with a segmented nucleus and dark-violet granules in the cytoplasm. Cat basophils have large, faint gray cytoplasmic granules

CLASSIFICATION OF ANEMIA

I. Erythrocyte volume and hemoglobin concentration
A. Mean corpuscular volume (MCV)
1. Microcytic anemia occurs when RBCs are small (decreased MCV), usually because of iron deficiency or sometimes portocaval shunts
2. Normocytic anemia occurs when RBCs are of normal volume (normal MCV)
3. Macrocytic anemia occurs when RBCs are larger than normal (increased MCV), indicating that the marrow is releasing immature cells

B. Mean corpuscular hemoglobin concentration (MCHC)
1. Hypochromic anemias are conditions where the RBCs contain less hemoglobin than normal (decreased MCHC)
2. Normochromic anemias are conditions where the RBCs contain a normal amount of hemoglobin (normal MCHC)
3. Hyperchromic anemias do not occur. MCHC can be falsely elevated when intravascular hemolysis is present

II. Responsiveness of bone marrow
A. Classified as regenerative or nonregenerative, based on the number of immature RBCs that circulate
B. Regenerative anemia indicates that there are increased numbers of immature RBCs in the circulation. An increase in immature RBCs is seen within 2 to 4 days after blood loss or destruction. In regenerative anemia, the reticulocyte concentration is greater than 60,000 cells/μL. Horses typically do not release reticulocytes into the circulation
1. From blood loss
a. Acute blood loss
(1) Acanthocytes and schistocytes are usually seen with hemangiosarcoma
(2) Typically see reticulocytosis, polychromasia, and thrombocytopenia
b. Chronic blood loss
(1) Results in iron deficiency anemia
(2) Decreased MCV (microcytosis), increased RDW, MCHC usually normal. Keratocytes and schistocytes are common

2. From destruction of blood
a. Immune-mediated hemolytic anemia. Spherocytes are common
b. Neonatal isoerythrolysis
c. Erythrocyte parasites
(1) *Mycoplasma haemofelis* (cats), *Mycoplasma haemocanis* (dogs), *Mycoplasma wenyonii* (cattle), *Mycoplasma haemosuis* (swine), *Candidatus Mycoplasma haemolamae* (llamas and alpacas). Adhere to surface of the RBC membrane
(2) *Anaplasma marginale* (cattle), *Anaplasma centrale* (cattle), *Anaplasma ovis* (sheep and goats). Dark blue inclusions in RBCs
(3) *Babesia canis* (dogs), *Babesia gibsoni* (dogs), *Babesia bovis* (cattle), *Babesia bigemina* (cattle), *Babesia equi* and *Babesia caballi* (horses), *Babesia ovis* and *B. motasi* (sheep), and *B. cati, B. felis, B. herpailuri, B. pantherae* (cats). Single or paired RBC inclusions
(4) *Theileria parva* and *Theileria annulata* (cattle), *Theileria lestoquardi* (sheep and goats). Signet-ring or comma-shaped

(5) Cytauxzoon felis (cats). Signet-ring shaped inclusions

d. Heinz body anemia. Caused by oxidant damage to RBCs, with denaturation of hemoglobin. Heinz bodies appear as small, pale structures near the margin of the RBCs, which may protrude. With methylene-blue staining, these appear blue
(1) Plant ingestion: *Allium* (onions and garlic), *Brassica* (cabbage, kale, rapeseed), red maple leaves (*Acer rubrum*)
(2) Chemical ingestion: Acetaminophen (cats), propylene glycol (cats), zinc, copper, methylene blue, crude oil (birds)
(3) Selenium deficiency (ruminants)
(4) Diabetes mellitus (cats)

e. Hypophosphatemia
(1) Postparturient hemoglobinuria (cattle)
(2) Diabetes mellitus (cats)
(3) Enteral feeding (especially cats)

f. Bacteria (*Clostridium, Leptospira*)
g. Viruses (equine infectious anemia)
h. Water intoxication (calves)
i. Membrane defects: Hereditary spherocytosis, hereditary stomatocytosis
j. Metabolic defects: Pyruvate kinase deficiency, phosphofructokinase deficiency, glucose-6-phosphate dehydrogenase deficiency, hereditary methemoglobinemia, porphyries

C. Nonregenerative anemia is characterized by a lack of immature RBCs when anemia is present and provides evidence for bone marrow dysfunction. Most are normocytic
1. Aplastic anemia (from infectious agents, toxins, drugs, or estrogen)
2. Pure red cell aplasia (decreased erythroid precursors in bone marrow)
3. Red cell hypoplasia (outside the bone marrow). Causes include inflammatory disease, chronic renal failure, endocrine disease, and nutritional deficiencies

POLYCYTHEMIAS

I. Increase in concentration of erythrocytes in the blood. Increased PCV, increased RBC count, increased hemoglobin concentration. The term *erythrocytosis* is more accurate

II. Relative polycythemia
A. Dehydration
1. Also see an increase in plasma proteins usually
2. May have normal or low plasma proteins depending on underlying conditions

B. Splenic contraction
1. Causes a mild increase in PCV (not greater than 60%)
2. May be secondary to excitement or exercise

III. Absolute polycythemia
A. Secondary
1. Generalized hypoxia
2. Increased erythropoietin production

B. Primary (primary erythrocytosis)
1. Bone marrow disorder
2. Cells appear normal, and maturation process is normal

LEUKOCYTE RESPONSES

I. Terminology
A. *–philia* as a suffix refers to an increase of that cell type
B. *–penia* as a suffix refers to a decrease of that cell type
C. *Left shift* is an increased concentration of immature neutrophils in the peripheral circulation. This can include band neutrophils, metamyelocytes, or other early forms
1. Left shift with neutrophilia suggests inflammation
2. Left shift with neutropenia indicates an aggressive inflammation with severe consumption of neutrophils

D. *Leukemia* is the presence of neoplastic cells in the peripheral circulation
E. *Proliferative disorder* refers to a blood cell neoplasia that is present in blood, bone marrow, or tissues
1. *Lymphoproliferative disorders* are neoplasias of lymphocytes. Lymphosarcoma (lymphoma) refers to neoplasia of lymphocytes within tissue. Lymphocytic leukemia is neoplasia within bone marrow and blood
2. *Myeloproliferative disorders* originate from stem cells in the bone marrow

II. Changes in morphology
A. Toxic change
1. Neutrophils have normal function
2. Neutrophils are produced at an accelerated rate in the bone marrow as a response to inflammation
3. Cytoplasm is basophilic due to increased ribosome content
4. Döhle bodies may be present in cytoplasm. These are aggregates of endoplasmic reticulum and are more commonly seen in cats
5. Cytoplasmic vacuolation may occur

B. Hypersegmentation of neutrophil nuclei occurs when neutrophils are retained in the peripheral circulation for a longer than normal time. This occurs in response to steroids
C. Degeneration of neutrophils is an artifact in blood that has aged for greater than 12 hours before making a blood smear. Cytoplasmic vacuolation and nuclear swelling are noted
D. Leukocyte agglutination occurs in vitro. It may cause a falsely low white blood cell (WBC) concentration.
E. Lymphocyte vacuolation may occur after ingestion of swainsonine (locoweed ingestion in horses or cattle). It also occurs in lysosomal storage diseases

III. Response to inflammation
A. In inflammation there is an increased demand for leukocytes as a result of consumption, and the

bone marrow should respond by releasing more leukocytes and increasing production
B. Most inflammation is associated with some degree of neutrophilia. The severity of the inflammation can be predicted by the degree of left shift and the toxic changes present
C. Neutropenia with left shift may occur when the consumption of neutrophils by the inflammatory process exceeds the bone marrow's capacity to produce neutrophils
D. There is species variation in the amount of bone marrow reserve to respond to inflammation. Dogs have a high marrow reserve and can respond with a significant neutrophilia. Cattle have limited bone marrow reserve, and cats and horses have an intermediate reserve

IV. Excitement response
A. Caused by epinephrine release, which shifts leukocytes from marginated pool to the circulating pool
B. Absence of a left shift
C. Recognized most frequently in cats, with lymphocytosis up to about 20,000 cells/μL

V. Stress response
A. Caused by a release of adrenocorticotrophic hormone (ACTH) causing increased cortisol concentration
B. Occurs with major systemic illness, pain, and metabolic disturbances
C. Lymphopenia is common
D. Numbers of neutrophils are often doubled as a result of longer retention in the circulation. Hypersegmentation of neutrophils may be seen. There is no left shift
E. Eosinopenia is often observed. Monocytosis usually occurs in dogs
F. If a steroid response is *not* present in a sick dog, hypoadrenocorticism should be suspected

VI. Approach to neutrophilia
A. Determine whether left shift is present. If a left shift is present, suspect inflammation
B. If there is no left shift, then look at lymphocyte numbers. If there is lymphopenia, consider a steroid response or possibly a steroid response combined with inflammation
C. If lymphocytes are normal or slightly increased, consider an excitement response

VII. Lymphocytosis
A. Excitement response. Lymphocytes are normal appearing
B. Lymphocytic leukemia
1. Abnormal morphology includes a large-diameter, lighter-staining nucleus, visible nucleoli, and increased amount of cytoplasm
2. Bovine leukemia virus with persistent lymphocytosis
C. Chronic canine ehrlichiosis

VIII. Neutropenia
A. Acute inflammatory consumption is accompanied by a left shift. Toxic neutrophil changes occur within a few days
B. Stem cell injury
1. Reversible
a. Typically accompanied by nonregenerative anemia and thrombocytopenia
b. Causes include chemotherapeutic agents, other drugs such as estrogen or phenylbutazone in dogs, and ehrlichiosis
2. Irreversible. Causes include feline leukemia virus (FeLV), hypoproliferative disorders, myelodysplasias, and myeloproliferative disorders
C. Approach to neutropenia
1. Determine whether also anemic. If so, then consider chronic bone marrow injury
2. If not anemic, then examine for left shift. If left shift is present, consider acute inflammation
3. If there is no left shift, consider acute viral infection or acute marrow injury

IX. Lymphopenia
A. Usually due to steroids
B. In Arabian foals, it may indicate an inherited severe deficiency of lymphocytes

X. Monocytosis
A. Relatively unimportant
B. Response to increased demand for macrophages in tissues

XI. Eosinophilia
A. Nonspecific response
B. Consider parasitism or hypersensitivity

XII. Basophilia
A. Uncommon
B. Interpretation unknown

BONE MARROW EVALUATION

I. Sites for collection
A. Dogs: Proximal end of the femur at the trochanteric fossa, the iliac crest, proximal humerus (Figure 3-3)
B. Cats: Trochanteric fossa and humerus
C. Horses, cattle, camelids: Ilium, ribs, or sternum

II. Indications
A. Nonregenerative anemia, neutropenia, thrombocytopenia, gammopathies, and possible neoplastic marrow disease
B. In horses, bone marrow evaluation helps determine whether anemia is regenerative because horses do not release reticulocytes

III. Erythroid cells (derived from stem cells)
A. Erythroid cells have round nuclei and moderate to deep blue cytoplasm that becomes pinker as hemoglobin is produced
B. Maturation sequence (immature to mature): Rubriblast, prorubricyte, rubricyte, metarubricyte, polychromatophilic erythrocyte, mature erythrocyte
C. Rubriblasts are the largest of the erythroid series, with round nuclei, slightly coarse chromatin, and nucleoli. There is little cytoplasm that stains dark blue
D. Prorubricytes do not have nucleoli, are smaller than rubriblasts, and have a little more cytoplasm
E. Rubricytes can still undergo mitosis, are smaller than prorubricytes, have very coarse chromatin, and polychromatophilic cytoplasm
F. Metarubricytes still contain a nucleus, are smaller than rubricytes, and have polychromatophilic cytoplasm

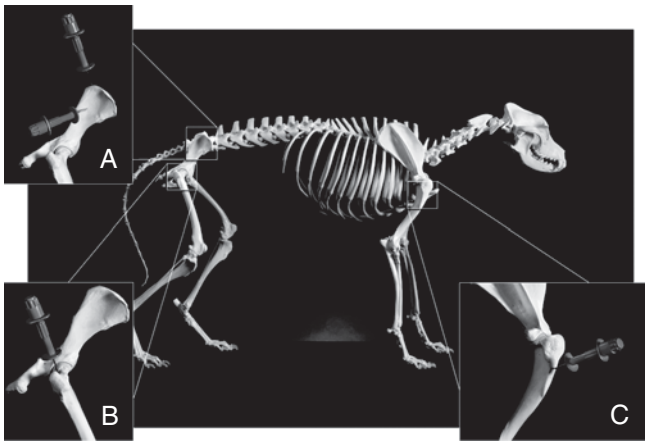


Figure 3-3 Dog skeleton showing common sites for bone marrow collection. In large dogs, the dorsal approach to the iliac crest **(A)** is an excellent site for aspiration and core biopsies. In small dogs and cats the lateral approach to the wing of the ilium **(A)** is a good site for core biopsies, and the trochanter fossa of proximal femur **(B)** is a good site for aspiration biopsies. For all small animals, the proximal humerus **(C)** is an excellent site for both aspiration and core biopsies. (Reprinted with permission from Grindem CD, Neel JA, Juopperi TA. Cytology of bone marrow. *Vet Clin Small Anim* 32[6]:1316, 2002.)

G. Polychromatophilic erythrocytes do not contain a nucleus, are blue-pink, and may contain nuclear remnants (Howell-Jolly bodies). When stained with methylene blue and reticulum is visible, they are termed *reticulocytes*

IV. Granulocyte (myeloid) cells (derived from stem cells)
- A. Granulocytes have irregularly shaped nuclei with fine chromatin patterns and lavender cytoplasm
- B. Maturation sequence (immature to mature): Myeloblast, promyelocyte, myelocyte, metamyelocyte, band neutrophil, segmented neutrophil
- C. Type I myeloblasts are the most immature, with a round to oval nucleus, nucleoli, small amount of blue-staining cytoplasm, and no azurophilic granules. The cytoplasm has a ground glass appearance and may contain small vacuoles
- D. Type II myeloblasts contain a few azurophilic granules (primary granules) in the cytoplasm; otherwise appear similar to type I myeloblasts
- E. Promyelocytes have many azurophilic granules in the cytoplasm; the nucleus is central to eccentric, and nucleoli are present
- F. Myelocytes can still undergo mitosis, are smaller than promyelocytes, have light blue cytoplasm, have no primary granules, and nuclei are round to oval. Secondary granules are present, so eosinophilic precursors contain pink granules, and basophilic precursors contain purple granules
- G. Metamyelocytes have kidney-bean–shaped nuclei, and are smaller than myelocytes
- H. Band neutrophils have horseshoe-shaped nuclei, with cytoplasm similar to segmented neutrophils

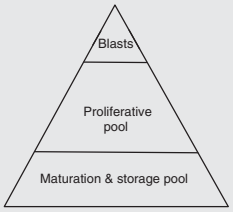
V. Monocyte cells (derived from stem cells)
- A. Difficult to distinguish from myeloid series. Monocyte cells have irregular nuclear outlines
- B. Maturation sequence (immature to mature): Monoblasts, promonocytes, monocytes
- C. Monocytes in bone marrow appear the same in peripheral blood. Precursors are difficult to identify unless there is a monocytic leukemia

VI. Megakaryocyte cells (derived from stem cells)
- A. Maturation sequence (immature to mature): Megakaryoblasts, promegakaryocytes, megakaryocytes
- B. Megakaryoblasts are larger than any other types of precursors
- C. Promegakaryocytes have two to four nuclei with a deep blue cytoplasm
- D. Megakaryocytes are very large, with numerous nuclei that are connected. The cytoplasm becomes granular and is sometimes light pink

VII. Other cells
- A. Lymphocytes appear as they do in the peripheral circulation
- B. Plasma cells are differentiated lymphocytes that produce immunoglobulin. They look similar to rubricytes, but the cytoplasm is more abundant in plasma cells and they have a clear perinuclear Golgi zone
- C. Lymphoblasts are rare, and their presence may indicate a lymphoproliferative disorder
- D. Macrophages
 1. Derived from monocytes
 2. In low numbers in bone marrow
 3. Cytoplasm is usually vacuolated, is gray-blue, and may contain small pink granules
 4. Macrophages phagocytize debris and often contain hemosiderin
- E. Osteoblasts and osteoclasts
 1. Osteoblasts appear similar to plasma cells but are larger
 2. Osteoclasts appear similar to megakaryocytes, but their nuclei are individual. Osteoclasts are specialized macrophages that lyse bone
- F. Mast cells are rare, large round cells with many metachromatic granules in the cytoplasm

VIII. Interpretation
- A. Cellularity
 1. Normal marrow is about 50% cells and 50% fat
 2. Hemodiluted samples are difficult to evaluate

Box 3-1 Normal Myeloid and Erythroid Maturation

Myeloid Series	Maturation Pyramid	Erythroid Series
Myeloblasts (< 5% of AMC)		Rubriblasts (< 5% of AEC)
Progranulocytes, myelocytes (~15% of AMC)		Prorubricytes, rubricytes (~65%-75% AEC)
Metamyelocytes, bands, segmented neutrophils (~80%-85% AMC)		Metarubricytes (~20%-30% AEC)

Cowell, RL, et al. *Diagnostic Cytology and Hematology of the Dog and Cat,* 3rd ed. St Louis, 2007, Mosby.

B. Megakaryocytes: Should be at least 5 to 10 megakaryocytes per slide
C. Myeloid-erythroid (M:E) ratio
 1. In general, M:E ratios are approximately 0.5:1 to 3:1
 2. Decreased M:E ratio suggests increased RBC production, decreased neutrophil production, or a combination
 3. Increased M:E ratio suggests increased myeloid cell production, decreased RBC production, or a combination
D. Maturation
 1. Approximately 80% to 90% of the cells should be more mature cells (metamyelocytes, bands, neutrophils; rubricytes, metarubricytes) (Box 3-1)
 2. Disorderly maturation suggests leukemia, myeloid hyperplasia, immune-mediated hemolytic anemia, or marked inflammation
E. Macrophages are usually present in small numbers. Increased numbers of macrophages may be seen in immune-mediated disorders or with other causes of increased cell destruction
E. Cytochemistry and immunophenotyping are available for definitive identification of cell types

Supplemental Reading

Thrall MA ed. *Veterinary Hematology and Clinical Chemistry*. Philadelphia, 2004, Lippincott Williams & Wilkins.

Villiers E, Blackwood L. *BSAVA Manual of Canine and Feline Clinical Pathology*. Gloucester, UK, 2005, BSAVA.

Willard MD, Tvedten H. *Small Animal Clinical Diagnosis by Laboratory Methods.* St Louis, 2003, Saunders.

4 CHAPTER

Dentistry

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CANINE AND FELINE DENTISTRY

Dental Anatomic Review

I. Dental formulas

	Deciduous Dentition	Permanent Dentition
Dog	2 (I3/3, C1/1, P3/P3) = 28 teeth	2 (I3/3, C1/1, P4/P4, M2/M3) = 42 teeth
Cat	2 (I3/3, C1/1, P3/P2) = 26 teeth	2 (I3/I3, C1/C1, P3/P2, M1/M1) = 30 teeth

A. Incisor teeth: There are three incisor teeth in each quadrant in dogs and cats, the 1st, 2nd, and 3rd incisors. These teeth are used for cutting and grooming

B. Canine teeth: There are a total of four canine teeth in the dog and cat. These teeth are used for puncturing and tearing

C. Cheek teeth: The cheek teeth are located behind the canine teeth and are divided into premolars and molars. Premolars are used for shearing, molars for crushing

1. Premolars: Adult dogs have four maxillary premolars and four mandibular premolars on each side. The 1st maxillary premolars are not present in the cat, and the 1st and 2nd mandibular premolars are not present in the cat. The maxillary premolars are the 2nd, 3rd, and 4th premolars in the cat. The mandibular premolars in the cat are the 3rd and 4th premolars
2. Molars: There are two maxillary molars on each side in the dog, the 1st and 2nd maxillary molars. In the cat there is only one very small maxillary molar on each side, the 1st maxillary molar. There are three mandibular molars on each side in the dog, the 1st, 2nd, and 3rd molars. In the cat there is one mandibular molar on each side, the 1st molar.
3. Carnassial teeth: The largest maxillary cheek teeth in the dog and cat are the maxillary 4th premolars. The largest mandibular cheek teeth in the dog and cat are the mandibular 1st molars. An easy way to remember the proper identification of the cheek teeth in the dog and cat is to remember that the largest cheek tooth in the maxilla is the 4th premolar and the largest cheek tooth in the mandible is the 1st molar and count rostrally or mesially.

II. Adult root structure

A. Dogs: All incisor and canine teeth have one root. The first maxillary cheek tooth (1st premolar) has one root, the next two (2nd and 3rd premolars) have two roots, and the next three (4th premolar, 1st molar, and 2nd molar) have three roots. The mandibular cheek teeth in the dog all have two roots except the first and last cheek teeth, which have one root

B. Cats: All incisor and canine teeth have one root. The first maxillary cheek tooth (2nd premolar) has one root, the next tooth (3rd premolar) has two roots, and the next tooth (4th premolar) has three roots. The small maxillary 1st molar in the cat has two small roots. The mandibular cheek teeth (3rd and 4th premolars and 1st molar) in cats all have two roots

III. Gross anatomy of the tooth and surrounding bone (Figure 4-1)

A. Crown: Portion of tooth that is normally visible in the mouth

B. Root: Portion of tooth that is imbedded in the bone of the maxilla or mandible

C. Enamel: Hardest substance in the body that covers the outer layer of the crown

D. Dentin: Intermediate layer of the tooth and forms the bulk of the calcified tooth structure

E. Pulp: Innermost layer of the tooth and consists of nervous, vascular, and loose connective tissue

F. Cementum: Covers the outer layer of the root of the tooth

G. Cemento-enamel junction: Separates the crown from the root and separates the portion of the tooth covered by either enamel or cementum

H. Furcation: The point at which the roots of a multirooted tooth branch from the crown

I. Apex: Tip of the root of a tooth through which blood vessels and nerves enter the tooth

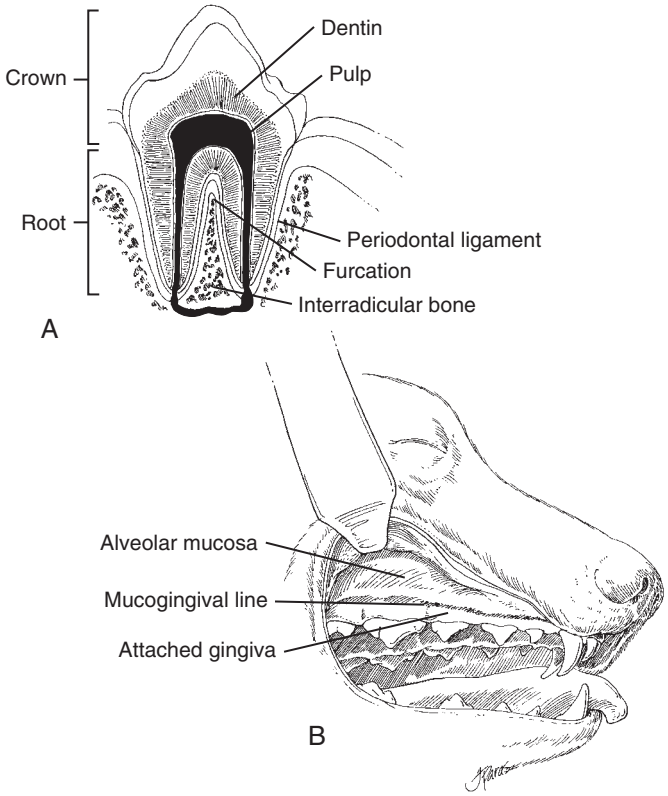


Figure 4-1 **A,** Anatomy of the tooth. **B,** Gingival anatomy. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

J. Gingival sulcus: Normal space between the edge of the gingival margin and the attachment of the tooth (normal depth of the gingival sulcus is no more than 1 to 3 mm in depth in dogs and 0.5 to 1 mm in cats)
K. Periodontal ligament: Collagenous fibrous bundles that attach the cementum of the root of the tooth to the alveolar bone (radiographically the periodontal ligament appears as a radiolucent [black] line around the roots of teeth)

IV. Tooth type. Brachyodont: Short crown-root ratio with a true root; once apex forms, tooth growth stops

Common Dental Diseases in Dogs and Cats

I. Periodontal disease
A. Pathophysiology: Most common disease diagnosed in dogs and very common disease in cats. Periodontal disease increases significantly with increasing age and is more severe in small-breed dogs. Periodontal disease is caused by an accumulation of bacteria in the form of plaque on the surface of the teeth, which causes inflammation of the surrounding tissues. As periodontal disease progresses, the periodontal ligament that attaches the root of the tooth to the alveolar bone is destroyed and attachment of the tooth to the bone is lost, the gingiva recedes, the furcation of multirooted teeth are exposed, and ultimately the attachment of the tooth is severely compromised, which results in tooth loss
B. Stages of periodontal disease and diagnostic evaluation
1. Stage I (gingivitis): Gingiva is inflamed but there is no attachment loss
2. Stage II (early periodontal disease): Periodontal probing and dental radiographs may indicate attachment loss of up to 25%, with the teeth remaining stable
3. Stage III (moderate periodontal disease): Periodontal probing and dental radiographs may indicate attachment loss between 25% and 50% of the root length, and teeth may begin to become mobile
4. Stage IV (severe periodontal disease): Periodontal probing and dental radiographs may indicate attachment loss greater than 50%, and there is severe loss of supporting tooth structures and teeth become loose
C. Clinical presentations of periodontal disease
1. Common clinical presentations of periodontal disease: Mobile teeth, periodontal and periapical abscesses with secondary facial swelling, gingival recession, mild to moderate gingival hemorrhage, and deep periodontal pockets with secondary oronasal fistula formation with secondary chronic rhinitis
2. Uncommon clinical presentations of periodontal disease: Severe gingival sulcus hemorrhage, pathologic mandibular fractures, painful contact mucosal ulcers, intranasal tooth migration, osteomyelitis, and ophthalmic problems

D. Treatment
 1. Dental charting with the patient anesthetized using a periodontal probe and dental radiographs to assess attachment loss
 2. Supragingival and subgingival scaling
 3. Root planning and subgingival curettage
 4. Polishing or irrigation
 5. Gingivectomy
 6. Open-flap curettage with augmentation of bony defects
 7. Perioceutics
 8. Exodontia (extractions)
 9. Oronasal fistula repair
 10. Home care

II. Endodontic disease
 A. Pathophysiology: Endodontic disease refers to disease of the pulp of the tooth or the inner aspect of the tooth that contains the blood vessels and nerves of the tooth. The most common cause of endodontic disease in small animals is dental trauma. A series of events may occur in some fractured teeth with exposed pulp, which can result in significant clinical problems. This series of events includes pulpal exposure, bacterial pulpitis, pulp necrosis, periapical granuloma, periapical abscess, acute alveolar periodontitis, osteomyelitis, and sepsis
 B. Teeth most commonly fractured
 1. Dogs: Canine teeth, incisors, and maxillary fourth premolars
 2. Cats: Canine teeth
 3. Any tooth in a dog or cat may be fractured, although less frequently
 C. Stages, clinical signs, and evaluation of endodontic disease
 1. Acute pulpal exposure (acute endodontic disease): Animals may hypersalivate, they may be reluctant to eat, and the tooth will bleed at the site of the pulpal exposure. A dental explorer under anesthesia can be inserted into the pulp canal and the pulp will bleed
 2. Chronic pulpal exposure: Facial swelling, sneezing, nasal discharge, or mucosal or cutaneous fistulas. A dental explorer under anesthesia can be inserted into the pulp canal, but the pulp is necrotic and will not bleed
 D. Radiographic changes associated with chronic endodontic disease
 1. Periapical lysis (radiolucency around apex or dark halo around root tip)
 2. Apical lysis (radiographic loss of the apex)
 3. Large endodontic canals compared with contralateral tooth (when teeth are affected with endodontic disease when a dog is young, the pulp remains large and dentin is not deposited in the tooth)
 4. Radiographic loss of tooth structure to pulp canal
 E. Treatment
 1. Vital pulpotomy: Limited to very recent pulpal exposure in young dogs with very large pulp canals and is an attempt to maintain the viability of the pulp until at least the tooth is mature and the pulp canal is more narrow and the dentin is thicker and stronger, at which time a conventional root canal procedure may be performed if necessary
 2. Conventional endodontic therapy or nonsurgical root canal therapy: Most common form of endodontic therapy involving removal of the pulp tissue through the crown of the tooth and placement of an inert material in pulp canal to prevent infection associated with necrotic pulp
 3. Surgical endodontic therapy: Rarely performed endodontic therapy and involves conventional endodontic therapy and amputation of the apex of the tooth with closure of the remaining apical portion of the root

III. Feline tooth resorptive lesions
 A. Pathophysiology: The cause of feline tooth resorptive lesions is unknown; however, proposed theoretical contributing factors in feline tooth resorption include excess vitamin D and excessive occlusal stress caused by eating large, dry kibble. Feline tooth resorptive lesions are caused by odontoclasts and can develop anywhere on the root surface, not just close to the cementoenamel junction; resorption on the enamel as the initial event is rarely observed. Resorptive lesions that occur at the cementoenamel junction are filled with highly vascular and inflamed granulation tissue. These lesions are often painful and bleed when probed with a dental explorer. Tooth resorption in cats is frequently progressive, and the resorptive lesions continue to enlarge until the roots of affected teeth are completely resorbed or the crown of the tooth breaks off, leaving behind remnants of resorbing roots
 B. Teeth affected by feline tooth resorptive lesions: All types of teeth may be affected, but the mandibular 3rd premolars are the most frequently affected teeth
 C. Clinical signs and evaluation of feline tooth resorptive lesions
 1. Resorptive lesions are often painful when the lesion involves the crown
 2. Lesions may be hidden from view by plaque, dental calculus, or inflamed gingival tissue
 3. Dental explorer used to localize lesions: when explorer encounters a resorptive lesion, it will fall into the irregular area of resorption
 4. Dental radiographs necessary to determine the full extent of the resorptive process and to determine the appropriate treatment plan
 D. Treatment options
 1. Restoration: Lesions that extend into the dentine but do not involve pulp tissue were previously restored; however, restoration of these teeth has been shown to be unsuccessful, so no longer recommended
 2. Conservative management: Resorptive lesions involving only the root and not the crown can be monitored both clinically and radiographically
 3. Whole tooth extraction: Ideal but often not possible with advanced lesions

4. Coronal amputation: Indicated when the crown is affected and the root has been extensively resorbed

IV. Feline gingivostomatitis
 A. Pathophysiology: The cause of feline gingivostomatitis, also referred to as lymphoplasmacytic stomatitis or lymphocytic plasmacytic gingivitis stomatitis, is unknown; however, there may be an immunologic basis for this condition and potential involvement of various viral agents
 B. Oral pathologic findings: Severe inflammation may be focal or diffuse, including gingivitis, stomatitis, and inflammation of the palatoglossal folds
 C. Diagnosis
 1. Feline immunodeficiency virus (FIV) and FeLV tests: Often negative
 2. Complete blood cell count (CBC) and serum chemistry: Hypergammaglobulinemia
 3. Histopathology: Submucosal inflammatory infiltrate of plasma cells, lymphocytes, macrophages, and neutrophils
 4. Dental radiographs: To rule out resorptive lesions and bone loss secondary to periodontitis or oral tumors
 D. Treatment options
 1. Initial treatment: Periodontal therapy and home care with corticosteroid and antibiotic therapy as needed
 2. Medical management alone often inadequate
 3. In refractory cases, extraction of the teeth is the treatment of choice (including all the premolars and molars, and in some cases all the teeth may require extraction)
 4. Other treatment options: Laser thermoablation combined with cyclosporine therapy if extraction of teeth is not desired

V. Miscellaneous small animal dental or oral diseases
 A. Normal occlusion and malocclusions
 1. Normal scissors bite: The upper incisors are rostral to the lower incisors
 2. Undershot (mandibular prognathic bite): The mandible is longer than the upper jaw, and the lower incisors are rostral to the upper incisors
 3. Overshot (mandibular brachygnathic bite): The mandible is shorter than normal, and the upper incisors are significantly rostral to the lower incisors
 B. Abnormal number of teeth
 1. Persistent or overly retained deciduous teeth: Common in small-breed dogs, and retained deciduous teeth should be extracted as soon as possible to help prevent the permanent teeth from erupting in abnormal locations
 2. Abnormal number of teeth
 a. Supernumerary teeth: Common in dogs and may be the result of either a genetic defect or a disturbance during tooth development and require extraction if causing dental crowding
 b. Oligodontia: A rare congenital absence of many but not all teeth
 c. Hypodontia: Absence of only a few teeth is a relatively common genetic fault often involving missing premolar teeth
 C. Dental wear
 1. Attrition: Dental wear caused by tooth-to-tooth frictional contact
 2. Abrasion: Dental wear caused by frictional contact of a tooth with a non-dental material
 3. Teeth respond to dental wear by laying down tertiary or reparative dentin, which is visible as a dark solid brown spot that cannot be entered with a dental explorer
 4. Very rapid dental wear may result in pulpal exposure that requires endodontic therapy or extraction
 D. Enamel hypoplasia
 1. Cause: A disruption of the ameloblasts during the first several months of life while the teeth are developing, which may be associated with periods of high fever, infections (especially canine distemper), nutritional deficiencies, disturbances in metabolism, systemic disorders, and trauma
 2. Disturbance in enamel formation over a longer period results in a more generalized distribution of lesions affecting multiple teeth in a bilaterally symmetrical manner while a solitary tooth that is affected with enamel hypoplasia is most likely the result of a focal traumatic episode
 3. Defective enamel is soft and porous, and the brittle enamel peels off exposing the underlying dentin, which is soon stained yellowish brown
 4. Treatment: Individual lesions can be restored; generalized lesions require diligent oral hygiene, fluoride treatment, and radiographic monitoring for endodontic disease
 E. Dental caries
 1. Cause: Demineralization of calcified dental tissues when plaque bacteria use fermentable carbohydrates as a source of energy
 2. Dental caries are rare in dogs compared with humans and have not been reported in cats; usually affect teeth with occlusal tables (molar teeth)
 3. Early dental caries may appear as dark brown spots and have a sticky or slightly soft feel when probed with a dental explorer
 4. Following perforation of the enamel, dental caries progress rapidly in the dentin, resulting in extensive loss of tooth structure with secondary pulpitis and pain and may result in pulp necrosis and periapical pathology
 5. Treatment: Restoration or extraction of affected teeth
 F. Lip-fold pyoderma
 1. Cause: Deep skin folds where the skin rubs against itself, causing irritation resulting in a pyoderma
 2. Skin folds create a moist, dark, and warm environment that supports the growth of bacteria or yeast and subsequent inflammation
 3. Dogs are often presented because of severe halitosis
 4. Breed predisposition: Cocker spaniel, springer spaniel, Saint Bernard

5. Treatment: Medical management can include gentle exposure and cleansing of the skin fold with an antiseptic shampoo, drying the area, and application of a mild astringent. Surgical removal of the skin fold provides a more permanent solution

G. Craniomandibular osteopathy
1. Cause unknown
2. Proliferative bone disease that results in the excessive deposition of periosteal new bone on the base of the skull and caudal aspect of the mandible
3. Breed predisposition: Most frequently seen in West Highland white terriers and Scottish terriers but occasionally seen in other breeds
4. Signalment and presenting signs include the following: Young immature dogs with intermittent fever, pain associated with attempting to eat and pain when opening the mouth. If excessive bone proliferation occurs, inability to open the mouth may be a complicating factor
5. Once skeletal maturity is reached and the physes close, bone proliferation decreases

H. Masticatory muscle myositis
1. Cause: Immune-mediated disease affecting muscles of mastication
2. Breed predisposition: German shepherd dogs and other adult large-breed dogs
3. Clinical presentation: Inability to open mouth with atrophy of muscles of mastication and severe temporal muscle atrophy
4. Diagnostics: Test for autoantibodies to type 2M myosin in muscle and serum and muscle biopsy demonstrates necrosis, phagocytosis, atrophy with fibrosis
5. Treatment: Forceful opening of mouth under general anesthesia with aggressive immunosuppressive doses of steroids tapered over 6 months

I. Common malignant oral tumors
1. Dogs: Melanoma, squamous cell carcinoma and fibrosarcoma
2. Cats: Squamous cell carcinoma (most common oral tumor in cats)

LAGOMORPH AND RODENT DENTISTRY

I. Lagomorphs
A. Lagomorphs: Rabbits
B. Dental formula: 2 (I2/1, C0/0, P3/2, M3/3) = 28
C. All teeth are radicular hypsodont teeth (i.e., teeth that never form a true root with an apex and the tooth grows continuously throughout life
D. Clinical signs of dental disease: Change in food preference, dropping food, anorexia, ocular or nasal discharge, hypersalivation, persistent grinding of teeth, inadequate grooming
E. Incisor overgrowth common in rabbits
1. Cause: Feeding diet with inadequate abrasive properties
2. Treatment: Correct cheek teeth overgrowth and extract or trim incisor teeth every 3 to 5 weeks as needed and switch to more abrasive diet (coarse hay)
F. Facial abscess common in rabbits
1. Cause: Secondary to periodontal or endodontic disease
2. Diagnosis: Oral examination and dental radiographs
3. Treatment: Extraction of affected teeth with surgical debridement of abscess and local antibiotic therapy

II. Rodents
A. Rodents: Guinea pig, chinchilla, rat, mouse, gerbil, hamster
B. Dental formula: Varies with species from 16 to 22 teeth
C. Aradicular hypsodont incisors and either aradicular hypsodont or brachyodont cheek teeth, depending on species
D. Clinical signs of dental disease similar to lagomorphs
E. Incisor overgrowth and cheek teeth overgrowth similar to lagomorphs, depending on species (Figure 4-2)

EQUINE DENTISTRY

I. Dental formula: 2 (I3/3, C0-1/0-1, P3-4/3, M3/3) = 36-42
II. Tooth type: Hypsodont dentition (long reserve crowns when young that shorten with age through attrition)

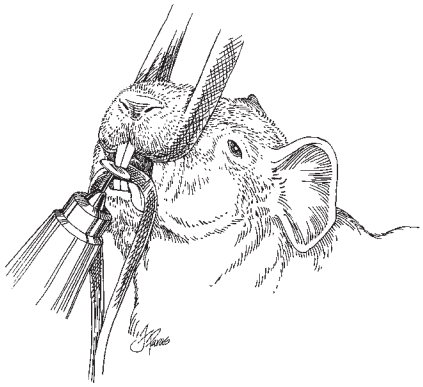


Figure 4-2 Proper technique for dental trimming. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice,* 3rd ed. St Louis, 2006, Saunders.)



Figure 4-3 Arabian horse, 2 years old. The deciduous incisors have small ridges and grooves on their labial surface. (From Baker G, Easley J. *Equine Dentistry,* 2nd ed. Kidlington, UK, 2005, Saunders Ltd.)

III. Age of horses and appropriate oral examination
 A. No permanent incisors under 2 ½ years (Figure 4-3)
 B. Eruption of I1: 2 ½ years
 C. Eruption of I2: 3 ½ years
 D. Eruption of I3: 4 ½ years
 E. In wear I1: 3 years
 F. In wear I2: 4 years
 G. In wear I3: 5 years
 H. Cup gone lower I1: 6 years
 I. Cup gone lower I2: 7 years
 J. Cup gone lower I3: 8 years
 K. Cup gone upper I1: 9 years
 L. Cup gone upper I2: 10 years
 M. Cup gone upper I3: 11 years
 N. Triangular I1: 16 years
 O. Triangular I2: 17 years
 P. Rectangular I1: 18 years
 Q. Rectangular I2: 19 years
 R. Rectangular I3: 20 to 21 years
IV. Common equine dental diseases
 A. Developmental diseases: Parrot mouth, a skeletal abnormality with the mandible significantly shorter than the maxilla
 B. Normal occlusion in horses is anisognathic (upper jaw is significantly wider than opposing mandible); this discrepancy in width results in natural attritional wear in horses that results in the formation of sharp projections on the buccal aspects of the maxillary cheek teeth and sharp points on the lingual aspect of the mandibular cheek teeth, which is treated by regular rasping (floating) of the cheek teeth every 6 months to prevent painful ulceration of the buccal and lingual mucosa by these points
 C. Acquired diseases
 1. Fractured teeth
 2. Periodontitis
 3. Periapical infection: Treatment extraction or endodontic therapy

Dental Anatomy

I. Dental formula
 A. The equine deciduous teeth dental formula is:

$$(\text{I } 3/3 \text{ P } 3/3) \times 2 = 24$$

 B. The equine permanent dental formula is:

$$(\text{I } 3/3 \text{ C } 1/1 \text{ P } 3 \text{ or } 4/3 \text{ M } 3/3) \times 2 = 44$$

II. Tooth surfaces
 A. Labial: The surface of the incisors and canines facing the lips
 B. Buccal: Surfaces of the cheek teeth in contact with the mucous membranes of the skin overlying them
 C. Lingual: Tooth surfaces in contact with the tongue
 D. Occlusal surface: The surface of the premolars and molars that contact those of the opposite jaw during the act of closure
 E. Incisal surfaces: Contact surfaces
 F. Coronal surface: Exposed crown
 G. Reserve crown: Unexposed crown (below the gingival margin)
 H. Tooth-gingival interface: The marginal border of a tooth

III. Numbering systems
 A. Standard
 B. Triadan: Uses quadrants (upper right is quadrant 1, upper left is quadrant 2, and so on)
 C. Modified triadan
IV. Anatomy
 A. Dentin
 1. Cream-colored substance composed of calcified tissue secreted by odontoblasts. Odontoblasts have their cell bodies in the pulp tissue and have long cell bodies that extend into mineralized dentin tubules
 2. Protects pulp from bacterial invasion as the pulp canal is exposed by wear
 3. Four types
 a. Primary: Produced during tooth development
 b. Secondary: Deposited on walls of the pulp canal and in the cytoplasmic processes
 c. Tertiary dentin: Produced to keep the pulp from being exposed
 d. Sclerotic: Produced in response to mild irritation
 B. Cementum
 1. Produced by cementoblasts
 2. 65% mineral, 35 % organic material, 5% water
 3. Covers entire surface of the tooth prior to eruption
 4. Fills in surface irregularities and protects enamel
 5. Has no blood supply after eruption
 C. Enamel
 1. Hardest substance in the body
 2. Secreted by ameloblasts
 3. 98% hydroxyapatite crystals and 2% keratinous proteins
 4. Inert substance (not living and therefore cannot repair itself)
 5. High tensile strength: Brittle
 6. Three types of enamel are produced in equine teeth, depending on where it is produced
 D. Pulp
 1. Loose connective tissue made of arteries, veins, nerves, lymphatics, odontoblasts, and fibroblasts that make up the pulp cavity of the tooth
 2. External nerve supply gives the tooth defensive capabilities
 E. Incisors
 1. Rip and tear forage
 2. Defense
 3. Used for aging a horse
 a. Deciduous
 (1) Smaller, whiter, and have a constricted neck
 (2) Do not have an infundibulum
 b. Permanent
 (1) Larger
 (2) Wider
 (3) Covered by yellowish cementum
 (4) No identifiable neck
 (5) Distinct vertical ridges

F. Canine teeth
 1. Used for fighting
 2. Usually found only in male horses
 3. Located in the interdental space (1 per arcade)
 4. Females rarely have canines (if so, located on mandible and is very small)
 5. Common to be thickly covered with tartar contributing to mild to moderate periodontal disease
 6. Large root = ⅔ to ¾ of the tooth
G. Wolf teeth
 1. Small, rudimentary teeth
 2. Usually present in both arcades in close proximity to the first cheek tooth
 3. Distinct neck and root
 4. May be present as unerupted
 5. Palatine artery is 2 to 3 mm medial to the maxillary cheek teeth and needs to be avoided when teeth are extracted
H. Cheek teeth (premolars and molars)
 1. Continuously erupting
 2. Self sharpening grinders
 3. Layer of cementum fills the infundibulum
 4. Different dental substances wear at different rates.
 5. 12 deciduous premolars erupt by birth to first week
 a. Shed at
 (1) 2 years, 8 months
 (2) 2 years, 10 months
 (3) 3 years, 8 months
 b. Differences between upper and lower cheek teeth
 (1) Maxillary have two distinct infundibuli, but mandibular have none
 (2) Maxillary teeth are wider and more square than mandibular teeth
 (3) Maxillary teeth have more prominent ridges than mandibular teeth on buccal aspects
 (4) Mandibular teeth are narrower, more oblong, and do not have longitudinal ridges
I. Supporting structures
 1. Supported via the dental arches, horseshoe-shaped dental ridges on the mandible and maxilla
 2. Teeth are supported in spongy osseous tissue called the *alveoli*
 3. Sinuses: Rostral and caudal maxillary sinuses
 a. Roots of the upper no. 8, 9, and 10 protrude into the rostral maxillary sinus
 b. Root of upper no. 11 protrude into the caudal maxillary sinus
 c. Surgical boundaries of the maxillary sinuses
 (1) Rostral rim of the orbit
 (2) Line connecting the end of the facial crest to the infraorbital canal
 (3) Facial crest
 (4) Line from the infraorbital foramen parallel to the facial crest
 4. Sinus and tooth root problems
 a. Tooth-root disease is a common cause of equine sinusitis, with damage to bony separation between caudal and rostral maxillary sinuses. Malodorous nasal exudate is a hallmark sign of tooth root disease in horses
 b. Infraorbital canal is closely associated with the roots of the upper teeth no. 8-11 (cheek teeth)
 (1) Nasolacrimal duct runs beneath the maxillary surface, dorsal and lateral to the canal
 (2) Both structures (infraorbital canal and nasolacrimal duct) can be easily injured via trauma and must be preserved during surgical treatment of diseased upper cheek teeth
 (3) Reserve root problems (especially tooth root abscessation and associated periodontal with or without bony involvement) is not uncommon in horses. Clinical signs include:
 (a) Malodorous breath
 (b) Malodorous nasal exudate
 (c) Weight loss
 (d) Muscle atrophy of associated arcade and hypertrophy of opposite side
 (e) Temporomandibular joint (TMJ)
 i. Allows for greater side-side movement
 ii. Works in a loose hinge-like movement
 iii. Dental disease can cause abnormal TMJ alignment with subsequent degenerative joint disease (DJD)

Dental Equipment

I. Dental floats
 A. Long straight float (push)
 B. Long straight float (pull)
 C. Long obtuse float (push)
 D. Long obtuse float (pull)
 E. Long closed angle float
 F. Short open angle float
 G. Offset float
 H. Short open angle float
 I. S-floats
 1. Power floats
 2. Bucket with disinfectant
 3. Cleaning equipment (brush to clean)
 a. Sedation
 b. Light source
 c. Dose syringe
 d. Cheek retractors
 e. Portable table
 f. Extra large halter and lead rope
 g. Head stand
 h. Extension cords

Equine Dental Examination

I. Dental disease is common; 25% to 80% of horses have dental disease

A. Signs of dental disease
 1. Clinical signs
 a. Weight loss despite good appetite
 b. Failure to gain weight
 c. Dribbling grain
 d. Chewing abnormalities
 e. Facial tenderness
 f. Accumulation of wads of grass in cheek
 g. Drooling
 h. Bad breath
 i. Excessive whole grain particles in manure
 j. Roughage particles longer than ¼ inch in manure
 k. Fistulous discharge from the face or jaw
 l. Swelling on the lower jaw or face
 2. Performance abnormalities associated with dental disease
 a. Head tossing
 b. Rearing
 c. Fighting the bit
 d. Refusal to take the bit
 e. Refusal to take the lead
 f. Refusing to take turns (racehorses, harness horses, barrel horses)

B. Working area
 1. Safe area
 2. Positioning
 a. Stocks
 b. Posterior stabilization (keep horse from moving backward)
 c. Side-to-side stabilization
 d. Room for examiner to work

C. Oral examination
 1. Brief dental examination: Incisors, first cheek teeth, mandibular manipulation to check for malocclusion
 2. Complete dental examination
 a. Sedation
 b. Thorough evaluation using speculum and light source

D. Dental charting: Triadan
 1. #100 = upper right quadrant (Figure 4-4)
 2. #200 = upper left quadrant
 3. #300 = lower left quadrant
 4. #400 = lower right quadrant
 5. 2nd number identifies tooth
 a. Central incisor = 01
 b. Intermediate incisor = 02
 c. Corner incisor = 03
 d. Canine = 04
 e. Wolf tooth = 05
 f. Cheek teeth = 06-11

Basic Dental Techniques

I. Reducing dental crown: Required for routine health maintenance since horses teeth continue to erupt (Figures 4-5 and 4-6)
 A. Also known as floating or rasping (goal is to remove sharp points that could interfere with normal eating)
 B. Upper arcades (maxillary arcade)
 1. Wider than mandible
 2. Upper buccal side of teeth is longer than lingual side (sharp points located on the buccal side)
 3. Lower arcade: Lingual side is longer (sharp points located on the lingual side)
 C. Flat surface of float blade is held perpendicular to the sharp enamel points

II. Retained deciduous caps
 A. Viewing of a retained tooth root crown above the occlusal surface of the rostral crown
 B. Use molar extractor
 C. Need to be removed to enable normal mastication

III. Hooks (rostral or caudal)

IV. Wolf tooth extraction
 A. Use wolf tooth extraction tool
 B. Remove all gingival and periodontal attachment
 C. Do not use tooth no. 6 as a fulcrum
 D. If tooth breaks – don't go digging, that may cause further trauma and damage
 E. Be careful to avoid the palatine artery

V. Cheek tooth extraction
 A. Oral extraction
 B. Repulsion
 1. Requires general anesthesia and a bone flap to expose the involved tooth
 2. May require referral for surgery

VI. Abnormalities of dental ware
 A. Wave mouth (Figure 4-7)
 1. Where the cheek teeth form an uneven or undulating occlusal surface
 2. May require aggressive rasping

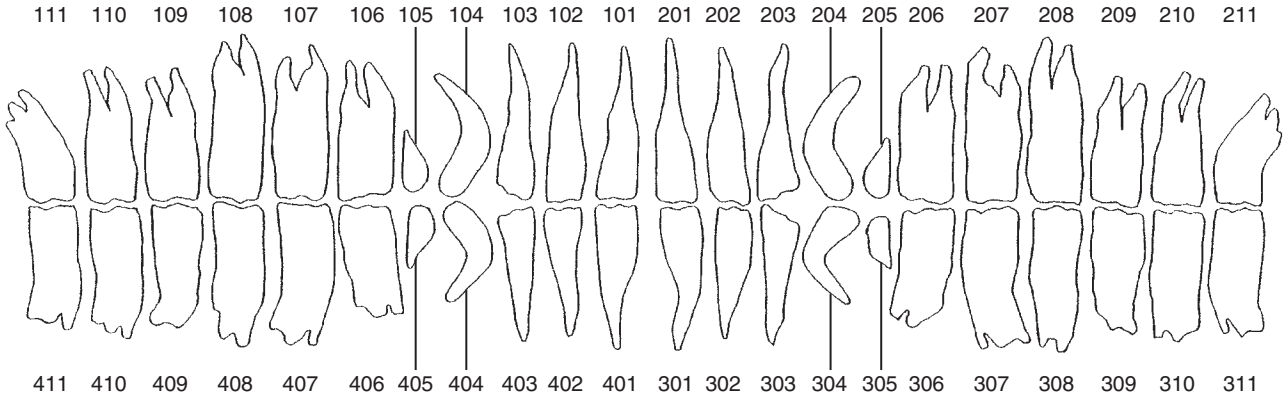


Figure 4-4 The Triadan classification of equine teeth. (From Baker G, Easley J. *Equine Dentistry,* 2nd ed. Kidlington, UK, 2005, Saunders Ltd.)

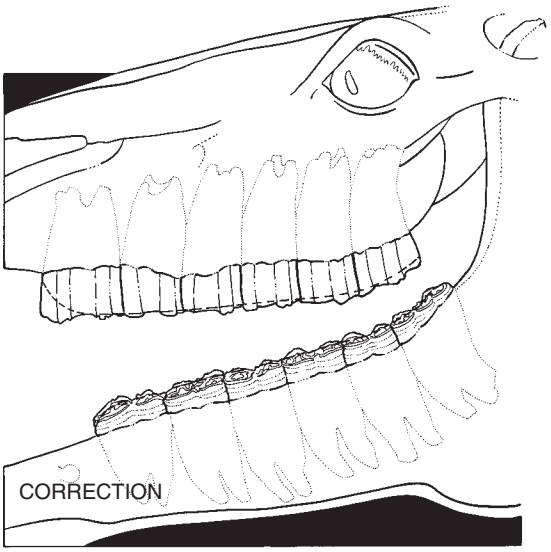


Figure 4-5 Normal mouth before dentistry. Lateral view—normal. No dentistry; sharp points; no bit seats. (From Allen T. *Manual of Equine Dentistry.* St Louis, 2003, Mosby.)



Figure 4-6 Normal mouth after dentistry. Lateral view—normal. Dentistry has been provided, points eliminated and bit seats installed. (Allen T. *Manual of Equine Dentistry*. St Louis, 2003, Mosby.)

3. More severe cases may require molar cutters
4. May require general anesthesia
5. Need to place cutter perpendicular to the teeth
6. Do not apply torque or tooth is likely to fracture
7. After cutting the tooth, the sharp edges should be rasped

B. Step mouth (overgrowth of opposing tooth will need to be rasped regularly)
C. Shear teeth (extreme exaggeration of the cheek teeth occlusal surface angulation and requires frequent rasping) (Figure 4-8)
D. Supernumerary teeth
 1. May be due to splitting of the dental bud
 2. May need to address via rasping tooth overgrowth



Figure 4-7 Lateral view—7, 8, 9 wave complex (8-high wave). No dentistry; sharp points; no bit seats. (From Allen T. *Manual of Equine Dentistry*. St Louis, 2003, Mosby.)

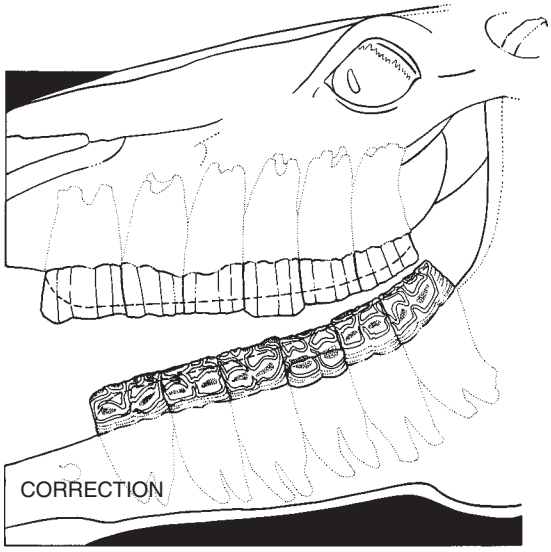


Figure 4-8 Lateral view of shear mouth of second and third quadrants; loose #309, overgrown #209. No dentistry; sharp points; no bit seats. (From Allen T. *Manual of Equine Dentistry*. St Louis, 2003, Mosby.)

Supplemental Reading

Gorrel C. *Veterinary Dentistry for the General Practitioner*. Philadelphia, 2004, Saunders.

Holmstrom SE. *Vet Clin North Am Small Anim Pract (Dentistry)* 35:4, 2005.

Kertesz P. *A Colour Atlas of Veterinary Dentistry & Oral Surgery.* Aylesbury, England, 1993, Wolfe Publishing.

Pasquini C, Spurgeon T, Pasquini S. *Anatomy of Domestic Animals,* 9th ed. Pilot Point, Texas, 1997, Sudz Publishing.

Verstraete FJ, ed. *Self-Assessment Colour Review in Veterinary Dentistry*. London, 1999, Manson Publishing Ltd.

Diagnostic Imaging

5 CHAPTER

Laura Jean Armbrust

GENERAL PRINCIPLES OF IMAGING

I. Image formation
 A. X-rays are produced by an x-ray tube and are controlled by the milliamperage (mA) and kilovoltage peak (kVp) settings
 B. Differential absorption of the x-rays within the body allows for differences in opacities on the radiograph
 C. Multiple forms of imaging are available
 1. Conventional film-screen radiography
 2. Digital radiography: Computed radiography (CR) and direct digital radiography (DDR)

II. Image interpretation
 A. Check for correct patient labeling, positioning, and inclusion of the entire area of interest
 B. At least two (orthogonal, at right angles) or more images should be made to correlate a two-dimensional (2-D) radiograph with a three-dimensional (3-D) patient
 C. There are five basic radiographic opacities. From least to most opaque these include air, fat, water or soft tissue, bone, and metal or contrast material
 D. Describe abnormalities in terms of the following: size, number, opacity, contour or shape, and location

SMALL ANIMAL ORTHOPEDICS

I. Normal. There is variation in the physeal closure time among animals. Radiograph the opposite limb when there is a question

II. Appendicular skeleton
 A. Traumatic disease
 1. Fracture detection and description
 a. Fractures are defined by the following:
 (1) Limb and bone involved
 (2) Fracture type
 (3) Direction of displacement
 (4) Articular involvement
 (5) Soft tissue changes
 b. Special classifications in animals with open physis: Salter-Harris classification
 2. Fracture healing
 a. Evaluate initial postoperative radiographs using the 4 A's:
 (1) Apposition
 (2) Alignment
 (3) Appliance
 (4) Articular surface
 b. Healing is usually through secondary bone healing that is seen on radiographs as the following:
 (1) First week: Increase in the width of the fracture gap
 (2) At 10 to 14 days, variable amount of callus begin to appear
 (3) At 4 to 8 weeks, fracture is less distinct with larger amounts of relatively smooth callus
 3. Fracture complications
 a. Nonunion: Lack of progression of healing after 16 weeks
 b. Malunion: Fracture healed in abnormal alignment
 c. Osteomyelitis: Variable osteoproductive and lytic
 d. Implant failure: Broken or migration of implants
 e. Angular limb deformity: Common in premature closure of the distal ulnar physis
 f. Sequestrum formation: Portion of bone lacking vascular supply is not incorporated in healing process
 g. Fracture associated sarcomas: Rare, approximately 5 years after fracture
 B. Aggressive bone disease
 1. Define by type of periosteal reaction, type of bone lysis, and zone of transition between normal and abnormal bone
 2. Types of periosteal reaction from least to most aggressive: Smooth, lamellar, irregular, sunburst, amorphous
 3. Types of bone lysis from least to most aggressive: Geographic, moth eaten, permeative
 4. The longer the zone of transition, the more aggressive the disease
 5. Neoplasia
 a. Variable degree of osteolysis and production
 b. Primary bone: Osteosarcoma most common (away from the elbow and toward the knee plus distal tibia). Usually does not cross joints
 c. Metastatic neoplasia to bone
 6. Infectious disease will have a variable degree of osteolysis and osteoproduction
 a. Granulomatous or fungal disease
 b. Osteomyelitis
 7. A bone biopsy is often required to get a definitive diagnosis

C. Congenital
 1. Polydactyly: One or more extra digits
 2. Syndactyly: Bony fusion of one or more digits
 3. Many types of dwarfisms and skeletal dysplasia occur but are uncommon. These usually result in abnormal ossification and shape/length of the skeleton

D. Developmental
 1. Panosteitis: Disease of young, large to giant breed dogs (Figure 5-1)
 a. Radiographs: Increased intramedullary opacity of long bones
 b. Most common in the German shepherd (can be seen in older shepherds) and basset hound
 2. Hypertrophic osteodystrophy (HOD): Disease of young large to giant breed dogs. Radiographs - abnormal lucent lines (double physeal line) in the metaphysis (most commonly the distal antebrachium) (Figure 5-2)

E. Hypertrophic osteopathy (HO) generally affects older dogs secondary to a thoracic (and less commonly abdominal) mass
 1. Radiographs: Palisading periosteal reaction and soft tissue swelling of multiple long bones; bilaterally symmetrical
 2. The periosteal reaction starts distally and eventually progresses up the limb
 3. Always take thoracic radiographs to check for a mass

III. Axial skeleton: Spine

A. Atlantoaxial subluxation
 1. Congenital malformation or hypoplasia of the dens
 2. Young small and toy breeds
 3. Be careful to avoid excessive flexion of the neck in these patients during radiography
 4. Radiographic findings
 a. Widening of the space between the atlas and spinous process of the axis
 b. Abnormal or absent dens

B. Cervical spondylopathy (wobbler syndrome, cervical vertebral instability)
 1. Young Great Danes and older Doberman pinschers
 2. Radiographic findings:
 a. Malformation of the vertebral bodies (C5-C7)
 b. Malalignment of the vertebral bodies
 c. Intervertebral disk space narrowing
 d. Spondylosis deformans
 e. Sclerosis of the vertebral end plates
 f. Degenerative changes of the articular facets
 3. Often need myelography for a definitive diagnosis

C. Lumbosacral instability
 1. Radiographic findings (note these same findings are found in dogs with degenerative disease that do not have signs of neurologic disease)
 a. Narrowing of intervertebral disk space at L7-S1
 b. Spondylosis deformans at L7-S1
 c. Sclerosis of the end plates at L7-S1
 d. Malalignment of the sacrum and L7
 2. Often need computed tomography (CT) or magnetic resonance imaging (MRI) to confirm

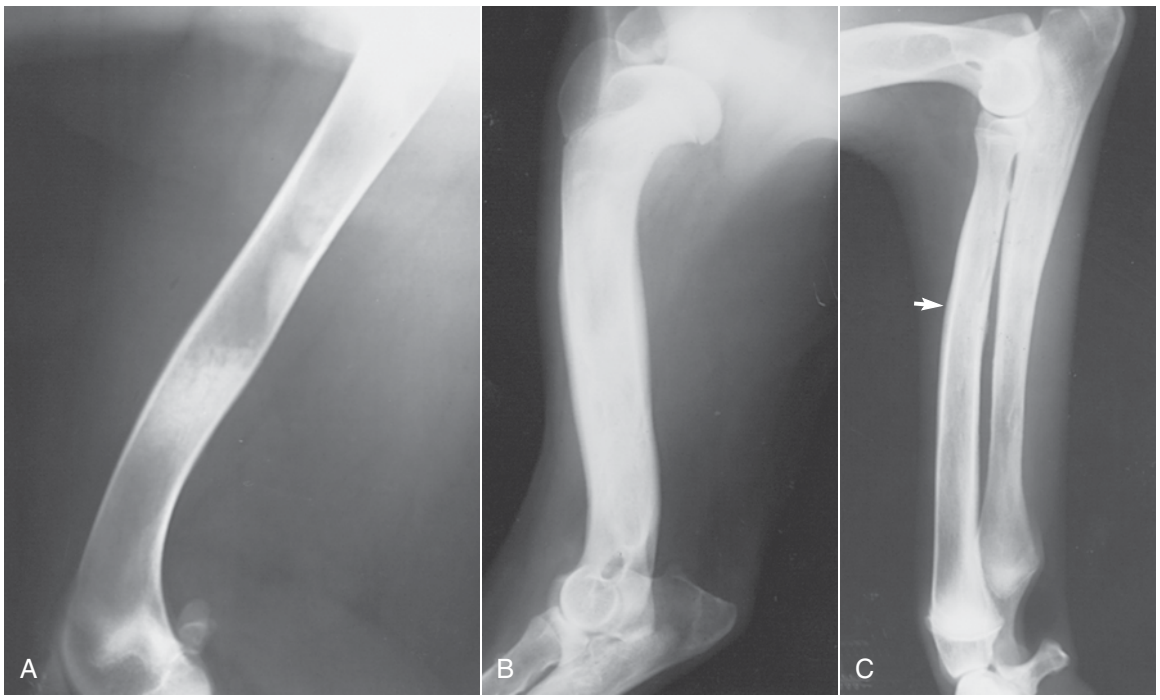


Figure 5-1 Stages of panosteitis. **A,** Early stage in a femur. Circumscribed increased opacity is visible in the mid-diaphysis and the proximal diaphysis. **B,** Middle stage in a humerus. Diffuse increased opacity of the entire diaphysis and a continuous periosteal new bone formation on the diaphysis are present. **C,** Later stage in radius and ulna. Less intense but still apparent increased opacity is visible, primarily in the proximal radius and ulna. Mild periosteal new bone formation is present on the cranial radius (*arrow*). (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

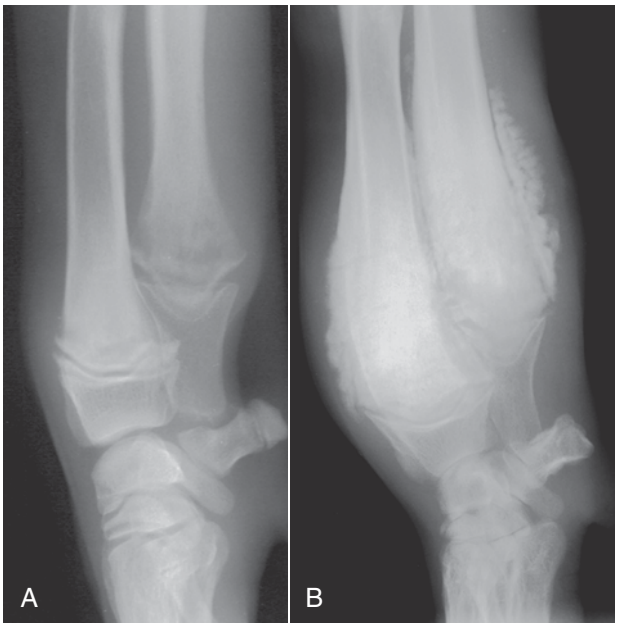


Figure 5-2 Hypertrophic osteodystrophy. **A,** Acute phase. Irregular radiolucent regions are evident in the distal radial and ulnar metaphyses, proximal to the physis. **B,** Chronic phase. An irregular, pallisading periosteal productive response surrounds the radial and ulnar metaphyses. The physes are relatively unaffected. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

D. Intervertebral disk disease
 1. Most common in chondrodystrophic breeds (dachshund)
 2. Radiographic findings
 a. Narrowing or wedging of the intervertebral disk space
 b. Narrowing of the intervertebral foramina
 c. Increased opacity in the spinal canal
 d. Narrowing of the joint space at the articular facets
 3. Myelography is performed to confirm a lesion prior to surgery
E. Spondylosis deformans
 1. Degenerative change of the spine
 2. Radiographic findings. Smooth new bone formation that may be bridging at the ventral (and sometimes lateral) vertebral endplates
F. Neoplasia
 1. Primary bone tumors generally affect one vertebra
 2. Spinal cord tumors usually cannot be detected without myelography
 3. Extension of neoplastic disease from the caudal abdomen and perineal tissues can result in osteolytic and osteoproductive changes at L5 through the sacrum and caudal vertebrae
G. Diskospondylitis
 1. Infection of the intervertebral disk space and adjacent vertebral endplates
 2. Radiographic findings
 a. Osteolysis of the vertebral endplates
 b. Multiple sites may be affected
 c. Widening or collapse of the intervertebral disk space
H. Trauma
 1. Compression fractures
 2. Subluxation and luxation

IV. Axial skeleton-skull
 A. Ear disease
 1. Otitis externa: Thickening and mineralization of the external ear canals, with partial to complete occlusion of the normally air filled canals
 2. Otitis media: Soft tissue or fluid opacity of the tympanic bulla with occasional changes in the bulla wall in severe cases
 3. Nasopharyngeal polyps: May see increased soft tissue opacity of tympanic bulla and nasopharynx
 B. Nasal disease: Usually divided into destructive or nondestructive rhinitis
 1. Destructive rhinitis
 a. Causes
 (1) Neoplasia: Adenocarcinomas most common
 (2) Fungal rhinitis
 (3) Chronic foreign bodies
 (4) Chronic inflammatory disease
 b. Radiographic findings
 (1) Increased soft tissue opacity in the nasal passages and frontal sinuses
 (2) Destruction of the nasal turbinates
 (3) Destruction of the bones surrounding the nasal passages, usually most severe with neoplasia
 2. Nondestructive causes
 a. Inflammatory disease
 b. Bacterial rhinitis
 c. Foreign bodies
 C. Dental disease: Peridontal disease is most common. Radiographic findings include the finding:
 1. Widening of the periodontal space
 2. Loss of the radiopaque lamina dura
 3. Root resorption
 4. Tooth loss
 D. Other
 1. Cranial mandibular osteopathy (CMO)
 a. Affects terrier breeds
 b. Radiographic findings:
 (1) Irregular new bone involving the mandibles and occasionally parietal, frontal, and maxillary bones
 (2) Can result in temporomandibular joint (TMJ) ankylosis
 2. Neoplasia: Can occur anywhere on the skull. Osteosarcoma is most common, with a variable degree of osteolysis and osteoproduction

V. Joint disease
 A. Traumatic
 1. Luxations and fractures
 2. Stress radiographs may be helpful to demonstrate instability
 B. Degenerative
 1. Commonly stifle secondary to cranial cruciate rupture, coxofemoral joints secondary to hip dysplasia, and elbow and shoulder joints
 2. Radiographic findings

a. Increased synovial mass/intraarticular swelling
b. Decreased joint space width
c. Periarticular osteophyte formation
d. Enthesopathy: New bone at soft tissue attachment sites
e. Subchondral bone sclerosis
f. Subchondral cystic changes in severe cases
g. Mineralization of soft tissues: Intra articular or periarticular

C. Neoplastic. Synovial cell sarcoma is most common
1. Destruction of subchondral bone
2. Soft tissue swelling

D. Inflammatory
1. Infectious
a. Hematogenous
b. Direct: Wounds, surgery, injections
c. Radiographic findings
(1) Subchondral bone lysis
(2) Intraarticular soft tissue swelling
2. Noninfectious: Immune mediated
a. Erosive
(1) Rheumatoid arthritis
(2) Greyhound polyarthritis
(3) Feline polyarthritis
(4) Radiographic findings
(a) Joint effusion
(b) Variable degree of subchondral bone lysis
(c) Decreased joint space width
(d) Variable degree of periarticular new bone
b. Nonerosive: Radiographs usually normal or show joint effusion
(1) Systemic lupus erythematosus (SLE)
(2) Idiopathic

E. Developmental
1. Osteochondrosis (OC) or osteochondritis dessicans (OCD)
a. Large and giant breed, young dogs
b. Failure of endochondral ossification
c. Common sites: Caudal humeral head, humeral condyle (medial aspect), stifle, tarsus (medial or lateral trochlear ridges)
d. OC has no flap; OCD has a mineralized flap or joint mouse
e. Radiographic findings
(1) Concave or flattened defect of the subchondral bone with adjacent bone sclerosis
(2) With or without bone flap at the site or within the joint
(3) Joint effusion
(4) Secondary degenerative joint disease
2. Hip dysplasia
a. All breeds of dogs and cats are affected, but it is most common in large- and giant-breed dogs
b. Radiographic findings:
(1) Incongruency or subluxation of the coxofemoral joints
(2) Poor coverage (less than 60%) of the femoral head by the dorsal acetabular rim
(3) Signs of degenerative joint disease (osteoarthrosis):
(a) Osteophytes at the cranial acetabulum
(b) Shallow acetabulum
(c) Remodeling of the femoral head and neck
(d) Enthesopathy at the joint capsule attachment
c. OFA (Orthopedic Foundation for Animals) and PennHIP are the two most commonly used regeristries
3. Elbow dysplasia
a. Ununited anconeal process: Anconeal process should fuse by 20 weeks (5 months)
b. Fragmented medial coronoid process: Often see the degenerative changes rather than the actual fragment
c. OC at the medial aspect of the humeral condyle
4. Avascular necrosis of the femoral head (Legg-Calves Perth disease)
a. Small and toy breed, young dogs affected
b. Radiographic findings
(1) Flattening/misshapen femoral head
(2) Increased and decreased opacity of the femoral head and neck
(3) Increased joint space width
(4) Fractures of the femoral head can occur
5. Patellar luxation
a. Most common in small and toy breeds
b. Medial luxation is more common than lateral
c. Lateral luxations usually occur in larger breeds
d. The luxation may be intermittent so may not always see on radiographs

SMALL ANIMAL THORACIC

I. General principles. Always take at least two orthogonal (i.e., lateral and dorsoventral [DV] or ventrodorsal [VD] views). When checking for pulmonary metastatic disease, both lateral views and the DV or VD should be taken. This is because the nondependent lung will be better aerated

II. Upper respiratory
A. Laryngeal
1. Laryngeal paralysis: Radiographs are usually normal
2. Laryngeal mass: Increased opacity in the laryngeal region. Can be caused by neoplasia, inflammatory disease, or foreign bodies

B. Tracheal
1. Tracheal collapse: Narrowing of portions of the trachea. Most common in toy to small breeds. Collapse of the intrathoracic trachea and mainstem bronchi is best seen on expiratory films. Fluoroscopy or endoscopy is useful for dynamic changes
2. Tracheal hypoplasia: Congenital narrowing of the entire trachea

3. Tracheal stenosis: Focal persistent narrowing of the trachea, usually secondary to previous tracheal trauma
4. Tracheitis: Usually radiographs are normal. Occasionally irregularity or thickening of the tracheal wall is present in severe cases

III. Pulmonary
- A. Evaluate the overall pulmonary opacity. Increased, decreased, or normal
- B. Pay close attention to distribution and location of disease: Focal, multifocal, diffuse, perihilar, craniventral
- C. Types of lung patterns (often combinations of the following patterns are present):
 1. Interstitial: Can be divided into structured (nodular) or unstructured (results in diffuse increase opacity without nodular form)
 2. Bronchial: Thickening of the bronchial walls and increased opacity within the lumen. Defined on radiographs as donuts in cross-section and tram lines in longitudinal section
 - a. Bronchiectasis: Defined as lack of normal tapering of the bronchi
 - b. Bronchial pattern is typically seen with inflammatory disease (either allergic or infectious). With feline lower airway disease, about 20% of patients will have collapse of the right middle lung lobe (right middle lung lobe syndrome)
 3. Alveolar: More severe increase in pulmonary opacity than that seen with interstitial disease. Will cause border effacement (results in loss of visualization of the margin) of pulmonary vessels and structures adjacent to the affected lung (diaphragm, heart, etc.). Can occur with fluid or cells. Distribution and duration of disease are important as discussed with specific diseases listed below.
 4. Vascular: An increase or decrease in the size of pulmonary arteries and veins. Most common abnormalities are listed below:
 - a. Heartworm disease: Increase in the size of the pulmonary arteries. Arteries become tortuous and blunted. Caudal lobar arteries are most commonly affected
 - b. Left-sided heart failure: Results in pulmonary venous distention; often concurrent pulmonary edema
 - c. Congenital diseases discussed below
- D. Patterns typical for specific disease
 1. Benign disease or artifacts
 - a. Pulmonary microlithiasis (pulmonary osteomata, pulmonary osseous metaplasia, dystrophic mineralization): Mineral opacities (smaller than 3 mm) throughout the lung
 - b. Artifacts include structures on the surface of the skin (e.g., debris, ticks), nipples, skinfold artifact, and costochondral junctions
 2. Pneumonia
 - a. Viral pneumonia: Normal to an unstructured interstitial pattern that is diffuse (sometimes most easily seen dorsally in the caudal lung lobes)
 - b. Bacterial: Typical distribution is cranioventral alveolar disease
 - c. Fungal: Structured interstitial pattern (miliary to nodular) that is diffuse. May see concurrent lymphadenopathy
 - d. Parasitic: Multifocal ill-defined nodular opacities
 3. Metastatic neoplasia: Most common pattern is a nodular pattern. Occasionally can see a somewhat unstructured interstitial pattern (lymphoma and mammary carcinoma)
 4. Primary neoplasia: Solitary lung lobe mass or diseased lung lobe. Caudal lung lobes most commonly affected but can occur anywhere
 5. Pulmonary edema (cardiac): Left-sided heart failure results in pulmonary edema that can have an interstitial to alveolar pattern. In dogs the distribution starts perihilar and spreads as severity increases. In cats there is no typical pattern of pulmonary edema
 6. Pulmonary edema (noncardiac). There are numerous causes, such as neurogenic (postseizure), electric cord shock, chocolate toxicity, vasculitis
 7. Pulmonary hemorrhage
 - a. Contusions can occur with trauma. Distribution is highly variable with and interstitial to alveolar pattern. Usually most severe within 24 hours of trauma
 - b. Anticoagulant toxicity: Distribution is variable
 8. Pulmonary abscess: Uncommon. May be focal or multifocal and either solid or cavitary
 9. Cavitary lesions. Differentials should include abscess, neoplasia, parasitic disease, and granulomas if the walls are thick and irregular. Smooth, thin-walled structures are cysts, bulla, blebs, or pneumatoceles. These are most commonly congenital or traumatic origin
 10. Lung lobe torsion: Increased opacity of the lung lobe with concurrent pleural effusion. May see abnormal location of the bronchus
 11. Pulmonary thromboembolic disease: Variable radiographic findings (often normal). Very early may see hyperlucency and lack of terminal vessel. Much more common to see increased opacity (focal interstitial to alveolar disease in caudal dorsal lung)
 12. Pulmonary infiltrates with eosinophilia (PIE): Multifocal, patchy interstitial to alveolar disease. Often seen with heartworm disease or other allergic or infectious causes

IV. Cardiac
- A. Congenital
 1. Patent ductus arteriosus (PDA) (left-to-right shunt): Ductus bump (enlargement of the proximal portion of the descending aorta) is the classic finding. May also see enlargement of the main pulmonary artery and left atrium or left auricle. Left-sided to generalized cardiac enlargement with pulmonary overcirculation (enlarged arteries and veins) may be present

2. Reverse PDA (right-to-left shunt): Generalized or right-sided heart enlargement with prominent main pulmonary artery. May not see ductus bump. Differential cyanosis
3. Pulmonic stenosis: Enlargement of the main pulmonary artery and right ventricle. Pulmonary vessels are normal to decreased in size
4. Aortic stenosis: Elongation of the heart with prominence of the aortic arch and left ventricular enlargement
5. Endocardial cushion defects (ventricular or atrial septal defects): Variable radiographic findings dependent on size of shunt. May range from normal to severe cardiomegaly
6. Tetrology of Fallot. Combination of the four following abnormalities:
 a. Pulmonic stenosis
 b. Right ventricular hypertrophy
 c. Overriding aorta
 d. Ventricular septal defect
7. Atrioventricular valve dysplasia
 a. Moderate to severe cardiomegaly
 b. Atrial enlargement: Left atrium is enlarged with mitral dysplasia; right atrial enlargement with tricuspid dysplasia
8. Vascular ring anomalies: Most common is persistent right aortic arch.
 a. Cardiac silhouette is normal
 b. Segmental dilation of the esophagus cranial to the base of the heart
 c. Barium esophagram may be needed for confirmation
 d. Aspiration pneumonia is often present (cranioventral alveolar pattern)

B. Acquired
1. Canine heartworm disease (Figure 5-3)
 a. Prominent main pulmonary artery with enlarged, tortuous, and blunted pulmonary arteries
 b. Enlarged right ventricle (reverse D shape of heart on VD radiograph)
 c. With or without patchy interstitial to alveolar pulmonary disease
2. Feline heartworm disease
 a. Unstructured interstitial pattern is most common; however, alveolar disease may occur
 b. Enlarged, tortuous pulmonary arteries may be present
 c. Variable right ventricular enlargement
3. Valvular insufficiency
 a. Mitral insufficiency: Enlarged left atrium in early disease. As duration and severity increase, left ventricular enlargement also occurs. The left-sided heart enlargement causes dorsal deviation of the trachea and mainstem bronchi (left mainstem bronchi may be compressed). If left-sided heart failure occurs, pulmonary venous distention and pulmonary edema will occur
 b. Tricuspid insufficiency: Usually does not occur as the primary problem but concurrently with mitral insufficiency



Figure 5-3 Dorsoventral thoracic radiograph obtained from a dog with chronic heartworm disease (HWD). Reader should note the enlarged main pulmonary artery, right ventricular enlargement, and enlarged, tortuous caudal lobar pulmonary arteries. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

 (1) Right atrial and ventricular enlargement (often see generalized cardiomegaly with both mitral and tricuspid valve insufficiency)
 (2) Right-sided heart failure leads to ascites and hepatic congestion and pleural effusion
4. Dilated cardiomyopathy
 a. Variable degree of cardiac enlargement ranging from normal to severe. Left atrial dilation and generalized cardiomegaly can be seen. Left-sided or right-sided (or both) heart failure can be seen
 b. Large to giant breeds, Doberman pinschers, boxers, and cocker spaniels are commonly affected breeds
5. Feline hypertrophic cardiomyopathy: Cardiac size may be normal
 a. Left ventricular enlargement
 b. Left or biatrial enlargement with classic "valentine"-shaped heart on the VD view
 c. Left-sided and right-sided heart failure can occur
 d. Echocardiography often recommended
6. Feline restrictive cardiomyopathy
 a. Mild to moderate cardiomegaly with left atrial dilation
 b. Pulmonary edema and pleural effusion often seen
7. Feline dilated cardiomyopathy (due to taurine deficiency). Generalized cardiac enlargement with right- or left-sided heart failure
8. Hyperthyroid cardiomyopathy

a. Ranges from normal to moderate cardiac enlargement
b. Heart failure can occur

9. Heart-base tumors
 a. Focal enlargement at the base of the heart is often masked by pericardial effusion
 b. Focal deviation of the terminal trachea over the base of the heart
10. Pericardial disease
 a. Pericardial effusion results in an enlarged, globoid shape of the cardiac silhouette. Type of effusion cannot be determined on radiographs (cytology is needed). Idiopathic effusion is most common. Masses may also be present so echocardiography is recommended (Figure 5-4)
 b. Peritoneopericardial diaphragmatic hernia
 (1) Inability to separate the apex of the heart and the diaphragm
 (2) Globoid enlargement of the cardiac silhouette
 (3) Cardiac silhouette may be inhomogenous opacity

V. Mediastinal
 A. Mediastinal shift refers to leftward or rightward shift of the cardiac silhouette on the VD or DV radiograph. Results from the following:
 1. Volume loss of lung (atelectasis); heart shifts *toward* the affected side
 2. Volume increase caused by intrathoracic or pulmonary mass; heart will shift *away* from affected side
 3. Obliquity of the patient can mimic a mediastinal shift
 B. Mediastinal masses
 1. The cranial mediastinum should be less than twice the width of the thoracic vertebrae on the DV or VD film in dogs. Symmetrical widening can be seen in fat animals
 2. The most common cause of a mass is lymph node enlargement (often secondary to lymphoma, other neoplasia, or fungal disease)
 a. On radiographs, cranial mediastinal lymph node enlargement causes widening of the cranial mediastinum and dorsal deviation of the trachea on the lateral view
 b. Perihilar (or tracheobronchial) lymphadenopathy is characterized by widening and bowing of the mainstem bronchi on the VD view and increased perihilar opacity on the lateral
 c. Sternal lymphadenopathy results in soft tissue opacity dorsal to the 2nd and 3rd sternebrae. These nodes drain portions of the mammary glands and cranial peritoneal cavity, so a cause for abdominal disease should be sought
 C. Pneumomediastium refers to the presence of gas in the mediastinal space. Radiographs are variable dependent on the amount of gas present. Patchy radiolucency and outlining of mediastinal structures with gas opacity may occur. Pneumomediastinum may lead to pneumothorax
 D. Mediastinal fluid results in symmetrical widening of the mediastinum. Positional radiographs may be helpful in determining if fluid is present

VI. Pleural
 A. Pleural effusion
 1. Overall increased thoracic opacity (variable dependent on the amount of fluid present) with border effacement of the cardiac silhouette and diaphragm (again degree is dependent on amount of fluid)
 2. Pleural fissure lines between lung lobes
 3. Separation of the lung from the thoracic wall with fluid opacity in the pleural space
 4. Differences between the VD and DV view occur. Heart is more readily apparent on a VD radiograph if fluid is present
 5. Differentials for fluid include transudates, modified transudates, exudates. These have numerous causes such as right-sided heart failure, chylous effusion, pyothorax, hemorrhage, neoplastic effusion.
 B. Pneumothorax
 1. Air within the pleural space results in separation of lungs from the thoracic wall
 2. The heart will appear dorsally elevated, with gas lucency below on the lateral radiograph
 3. Lack of visualization of vessels beyond the margin of the lungs
 4. Variable collapse and increased opacity of the lung lobes. If lung lobes are collapsed, a tension pneumothorax is present. This is an emergency situation

VII. Thoracic wall: Abnormalities involve the ribs or soft tissues
 A. Masses may be neoplastic or infectious (abscess or granuloma). Hemorrhage secondary to trauma is generally more diffuse

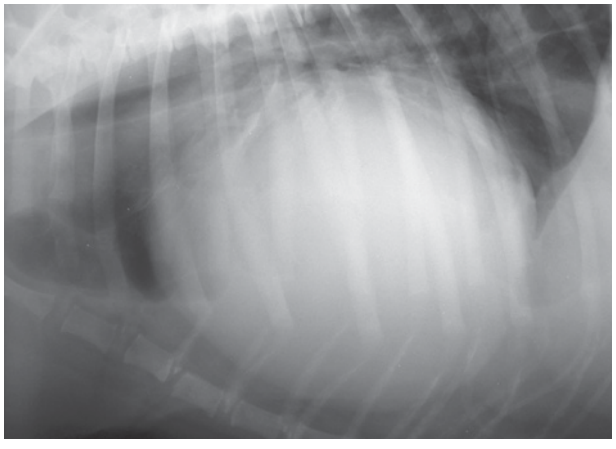


Figure 5-4 Lateral thoracic radiograph of a dog with severe, chronic pericardial effusion. Cardiac silhouette is globoid and overlaps diaphragm, and trachea is elevated. A total of 1600 mL of pericardial effusion was removed by pericardiocentesis. Histopathology of the pericardium disclosed pericardial mesothelioma. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

B. Rib fractures are commonly overlooked
C. Congenital pectus excavatum is seen as dorsal elevation of the caudal sternebrae. This results in a shift of the cardiac silhouette. Clinical significance is variable

SMALL ANIMAL ABDOMINAL

I. General abdomen
 A. Decreased abdominal serosal detail may be due to the following:
 1. Emaciation
 2. Patient age: Animals younger than 6 months will have poor detail
 3. Abdominal fluid or infiltrative disease (peritonitis or carcinomatosis)
 B. If a mass (can see margins) or mass effect (cannot see margins of mass, but organs are displaced) is seen, consider the following:
 1. What are the potential organs of origin?
 2. What are the differentials for a mass?
 a. Neoplasia
 b. Hematoma
 c. Granuloma
 d. Abscess
 e. Cyst
 C. Hernias: Look for abdominal organs in abnormal locations
 1. Diaphragmatic
 2. Umbilical
 3. Inguinal
 4. Perineal
II. Hepatic disease
 A. Generalized hepatomegaly
 1. Radiographic findings
 a. Caudal displacement of the gastric axis (caudodorsal displacement of the pylorus)
 b. Rounding of the caudoventral margin of the liver
 2. Differentials should include: Metabolic, endocrine, inflammatory/infectious, and diffuse infiltrative neoplastic disease. Nodular regeneration may also be present
 B. Focal hepatic mass. Radiographic findings include the following:
 1. Displacement of structures (mainly the stomach) based on location
 2. Pedunculated masses may extend caudal to the stomach. Differentials include neoplasia, abscess, granuloma, hematoma, and cyst
 C. Multifocal disease or irregularity of the liver margins. Differentials would include metastatic neoplasia, nodular regeneration, abscesses, or granulomas
 D. Microhepatica (decreased liver size): Cranial displacement of the gastric axis
 1. Portosystemic shunt
 2. Chronic fibrosis or cirrhosis
 E. A normal-sized liver does not rule out hepatic disease. Abdominal ultrasound should be performed if clinical signs or laboratory abnormalities suggest liver disease
 F. Gallbladder
 1. Cholecystitis: Radiographs are normal
 2. Cholelithiasis: Radiopaque calculi in the gallbladder. Most often and incidental finding
III. Splenic disease
 A. Generalized splenomegaly: Evaluation of the spleen for size is extremely subjective
 1. Radiographic findings
 a. Rounding of the margins
 b. Increased thickness
 2. Differentials include drug-induced (tranquilization), immune-mediated, inflammatory or infectious, vascular congestion, diffuse neoplasia, and extramedullary hematopoiesis
 B. Focal splenic mass
 1. Radiographic findings
 a. Because the body and the tail of the spleen are very mobile, a splenic mass or mass effect can be seen in almost any location between the stomach and bladder
 b. With or without abdominal effusion
 2. Differentials include neoplasia, hematoma, abscess, granuloma, and nodular hyperplasia
 C. Splenic torsion
 1. Large, deep-chested dogs
 2. Radiographic findings:
 a. Abnormal location
 b. Moderate to severe enlargement
IV. Urinary tract disease
 A. Renal and ureters
 1. Congenital
 a. Renal aplasia, hypoplasia, dysplasia: Kidney is absent or small
 b. Ectopic ureters: Survey radiographs are normal
 (1) Contrast study should include pneumocystography (negative contrast air infused in bladder) with a concurrent intravenous pyelogram (IVP) or excretory urogram (EU); sometimes a positive contrast vaginogram may also be useful
 (2) Radiographic findings for IVP
 (a) Normal to dilated ureters and renal pelves
 (b) Ureter bypasses the normal insertion at the trigone and empties into the urethra or vagina
 2. Renal cysts
 a. Solitary cysts: Usually not seen on radiographs but can occasionally become large enough to deform the cortex
 b. Polycystic kidney disease: Primarily Persian-related breeds. Normal to enlarged kidneys with smooth to irregular margins
 3. Pyelonephritis: Radiographs often normal but may see mild renal enlargement
 4. Perinephric pseudocyst: Fluid around the kidney. Enlargement of the renal silhouette; margins are smooth
 5. Hydronephrosis: Radiographs are normal until disease becomes severe, then renal enlargement occurs. Often unilateral enlargement but can be bilateral

6. Renal neoplasia: Metastatic or primary tumors; may be unilateral or bilateral. Radiographic findings:
 a. Kidneys may be normal on survey radiographs
 b. Uniform to focal enlargement
 c. Margins may be smooth or irregular
7. Renal mineralization
 a. Mineralization may occur in either the renal pelvis (nephroliths) or renal parenchyma (nephrocalcinosis)
 b. It is not always possible to tell where the mineralization is located

B. Bladder
1. Bladder rupture. Radiographic findings include the following:
 a. Abdominal effusion
 b. Best diagnosed with positive contrast cystogram
2. Cystic calculi. Radiographic findings include the following:
 a. Radiopaque calculi can be seen on survey films: struvite and calcium oxalate
 b. Nonradiopaque calculi require ultrasound or a double-contrast cystogram (calculi are visible as filling defects in the center of the contrast material)
3. Bladder neoplasia: Usually not seen on survey radiographs unless mineralization is present. Double-contrast cystogram: Irregular mucosal surface with thickened wall
4. Cystitis: Usually normal radiographs unless concurrent calculi present. Double-contrast cystogram: Irregular mucosal surface with mild wall thickening; usually cranioventral in location
5. Emphysematous cystitis: Air within the wall of the urinary bladder; sometimes seen in diabetic patients

C. Urethra
1. Urethritis: Thickening of the wall and irregular mucosal surface seen with a positive contrast urethrogram
2. Ruptured urethra: Leakage of positive contrast into the soft tissues during a urethrogram
3. Urethral calculi: Will see radiopaque calculi on survey radiographs
 a. Take a perineal view in male dogs to assess the penile urethral
 b. Calculi will appear as filling defects on a positive contrast urethrogram
4. Urethral neoplasia: Thickening of the wall and irregular mucosal surface seen with a positive contrast urethrogram

V. Gastrointestinal (GI) disease

A. Esophagus
1. Megaesophagus
 a. Focal or generalized; review many causes
 b. Radiographic findings (Figure 5-5)
 (1) Gas, fluid, soft tissue distention (may be focal or generalized) of the esophagus
 (2) Dorsal tracheal stripe if gas in the esophagus dorsal to the intrathoracic trachea
 (3) Ventral deviation of the trachea
 (4) Aspiration pneumonia: Alveolar pattern in cranioventral lung

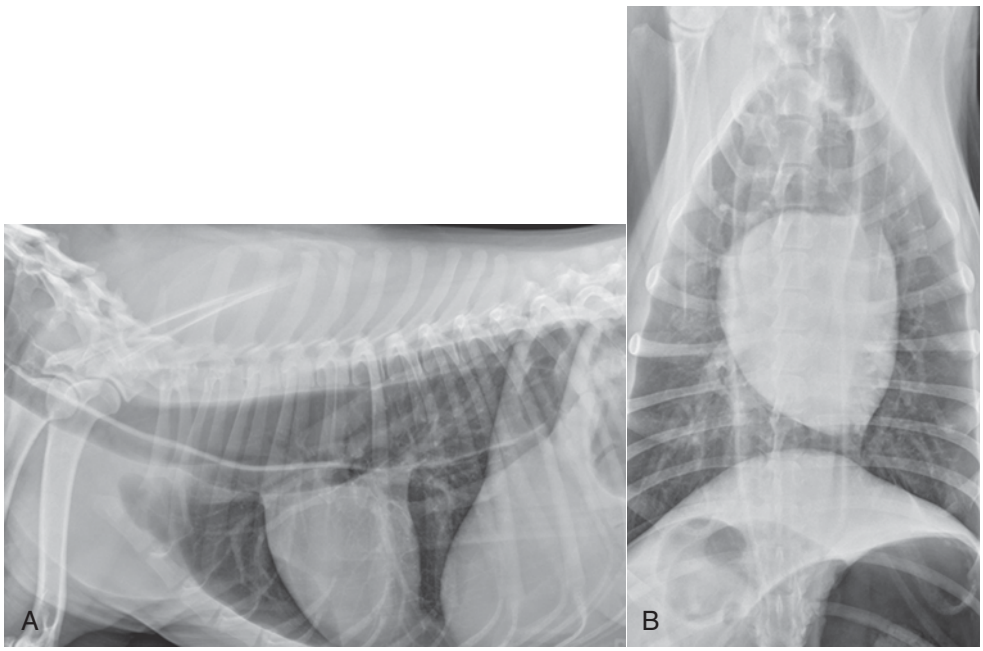


Figure 5-5 Lateral **(A)** and ventrodorsal **(B)** radiographs of a dog with generalized megaesophagus; the esophagus is filled with gas. **A,** Note the sharp demarcation between the esophagus and longus coli muscles, the ventral depression of the trachea, the long tracheal stripe sign, and the visibility of the esophageal walls in the caudal aspect of the thorax. A dilated esophagus is more difficult to see in the ventrodorsal view, but in this patient note the radiopaque lines paralleling the spine on each side of the thorax and how these lines converge caudally as they approach the stomach **(B).** (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

(5) An esophagram (barium) may be useful for determining the extent

2. Foreign bodies
 a. Radiopaque determined based on location from survey radiographs
 b. Non radiopaque can be diagnosed as filling defects with a positive contrast esophagram

B. Gastric disease
1. Gastric dilation (GD)
 a. Stomach air, fluid or ingesta dilated
 b. Normal positioning
2. Gastric dilation volvulus (GDV) (Figure 5-6)
 a. Preferred view is right lateral view
 b. Radiographic findings
 (1) Stomach is fluid, ingesta, or gas distended
 (2) Fundus: Displaced caudal, ventral, to right
 (3) Pylorus and duodenum: Displaced cranial, dorsal, to left
 (4) Compartmentalization: Soft tissue band dividing fundus and pylorus
 (5) Splenomegaly
 (6) Intestinal ileus (dilation of small bowel)
 (7) Megaesophagus
 (8) Hypovolemia (decreased size of cardiac silhouette, pulmonary vessels and caudal vena cava)
 (9) Plus or minus necrosis of stomach wall: Mural or free peritoneal air
3. Gastric foreign body
 a. Easily seen if radiopaque. Zinc toxicity may result from pennies
 b. Left lateral view will redistribute gas to pylorus and may help to outline pyloric foreign material
4. Gastric neoplasia: Survey radiographs are often normal



Figure 5-6 Gastric volvulus, right recumbent lateral view. The pylorus (P) is directed cranioventrally. Compartmentalization of the stomach is evident. Most of the small intestine is moderately distended, suggesting paralytic ileus. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

5. Gastric emptying disorders
 a. Functional ileus versus mechanical obstruction
 b. GD even after 24 hours without food (NPO)
 c. Radiographic findings
 (1). Fluid, gas, ingesta filled stomach
 (2). Often see small mineral opacities at pylorus (gravel sign)
 (3). Left lateral view is best to assess pylorus (foreign material or mural disease-hypertrophy or neoplasia)

C. Small intestine
1. Foreign bodies/intestinal obstruction
 a. Radiographic findings dependent on duration of disease, location of obstruction, and degree of obstruction
 b. Radiographic findings:
 (1) Segmental distention of small intestine (some loops dilated, others normal): Moderate to severe
 (2) May see foreign material if radiopaque
 (3) With or without free gas if intestine has perforated
 c. Linear foreign bodies: Do not see the distention as with other types of obstruction; instead, see placation of the bowel (abnormal cresent- or comma- shaped gas pattern)
2. Mural disease
 a. Radiographic findings depend on degree of obstruction
 b. Most commonly see signs of mechanical obstruction as listed above for foreign bodies
 c. Neoplasia: Adenocarcinoma and lymphoma most common
3. Intussusception: May see intussusception itself but more commonly see signs of mechanical obstruction
4. Enteritis or inflammatory bowel disease: Normal radiographs to mild generalized distention of small intestine
5. Mesenteric volvulus: Radiographic findings include the following:
 a. Severe generalized gas distention of bowel
 b. With or without free abdominal gas and fluid
 c. Irregularity to mucosal surface

D. Large intestine
1. Colitis: Radiographic findings include (often seen in normal radiographs) the following:
 a. Fluid-filled colon
 b. Corrugation
 c. Wall thickening: Difficult to assess without contrast
2. Neoplasia: May see mural thickening if outlined by gas or distention of the colon if obstructed
3. Megacolon: Functional or mechanical. Radiographic findings include a fluid or feces distended colon

E. Contrast procedures
1. Pneumogastrogram: Negative contrast in stomach. Useful for identifying foreign material or mural disease

2. Gastrogram: Positive contrast
 a. Useful for identifying foreign material or mural disease and stomach location (hernia or liver size)
 b. May have to wait until stomach empties to identify foreign material
3. Upper GI: Barium (15% to 30% wt/vol) administered via a tube into the stomach at approximately 5 mL/lb; radiographs taken immediately, then at various intervals depending on patient disease and motility. Useful for foreign bodies including linear foreign bodies, mural masses, intestinal perforation, location of bowel, and motility disorders (gastric emptying or functional ileus)
4. Pneumocolon: Infuse air into descending colon. Useful for determining location of colon and mural disease
5. Partial barium enema
 a. Administer barium into descending colon
 b. Useful for determining location of colon and mural disease
6. Compression radiography: Use a radiolucent spoon to compress area of interest, thus displacing overlying structures
 a. Useful in areas of the abdomen that are outside the rib cage
 b. Can be used for other organs in addition to the GI tract

VI. Reproductive tract disease
 A. Prostatic disease
 1. The prostate should not be seen in neutered dogs; in intact dogs, it should be less than 70% of the pelvic inlet height and is generally much less than that
 2. Prostatic enlargement will result in cranial displacement of the urinary bladder and dorsal displacement of the colon
 3. Prostatic enlargement may be caused by benign hypertrophy (intact male only), prostatitis, neoplasia, prostatic cyst, prostatic abscess, or paraprostatic cyst
 4. If there are medial iliac lymph node enlargement and aggressive bone changes in the caudal lumbar spine, then neoplasia is the primary differential
 B. Testicle: With cryptorchidism there are usually no radiographic abnormalities. May see as a mass or mass effect in the mid to caudal abdomen if the testicle becomes abnormal (torsion or neoplasia)
 C. Ovarian disease
 1. Ovarian enlargement may result from cyst, abscess, or neoplasia (granulosa cell tumor, teratoma, adenocarcinoma)
 2. May not see on radiographs
 3. If severely enlarged will see a mass caudal to the kidneys with ventromedial displacement of bowel
 D. Uterus
 1. The gravid uterus is not recognized on radiographs before 25 to 30 days' gestation
 2. Mineralization of the fetal skeleton can be seen at 42 to 45 days in dogs and 35 to 40 days in cats
 3. Fetal death: Radiographic findings include the following:
 a. Gas within the uterus or fetus
 b. Overlapping of bones of the skull
 c. Lysis of the fetal skeleton
 d. Abnormal alignment of the spine and limbs
 4. Uterine enlargement: Differentials should include pregnancy, pyometra, mucometra, and hydrometra. Pyometra shows a tubular mass in the caudoventral abdomen resulting in craniodorsal displacement of the small bowel on the lateral view and medial displacement on the VD view. Compression radiography may help identify the uterus between the bladder and colon on the lateral view

VII. Other
 A. Pancreas
 1. Pancreatitis. Radiographic findings include the following:
 a. Increased soft tissue opacity caudal to the stomach
 b. Decreased serosal detail caudal to the stomach
 c. Widening of the gastroduodenal angle or displacement of the proximal duodenum to the right
 d. Displacement of transverse colon caudally
 e. Gas within the duodenum and colon-ileus
 2. Pancreatic masses. Radiographic findings include the following:
 a. Mass or mass effect caudal to the stomach
 b. Displacement of the colon caudally
 c. With or without abdominal effusion
 B. Adrenal
 1. Adrenal enlargement is usually not seen on survey radiographs unless severe
 2. Severe enlargement will result in a mass or mass effect in the retroperitoneal space displacing the kidneys caudolateral
 3. Hyperadrenocorticism. Radiographs may be normal. Radiographic findings include the following:
 a. Pendulous abdomen
 b. Diffuse hepatomegaly: Rounding of the caudoventral liver margin
 c. Pulmonary mineralization: Diffuse unstructured
 d. Mineralization of the skin (calcinosis cutis) or other soft tissues
 e. Uncommon to see adrenal mass. Adrenal mineralization can be seen in normal cats or with neoplasia
 C. Lymph node
 1. Normal lymph nodes are not seen on survey radiographs
 2. Radiographic enlargement is generally caused by neoplasia (lymphoma being common) or granulomatous disease. Reactive lymph nodes from other disease rarely get large enough to identify on radiographs
 3. Masses or mass effects in the central abdomen and ventral to the caudal lumbar vertebrae (medial iliac)

LARGE ANIMAL ORTHOPEDICS

I. Pedal bone
 A. Pedal osteitis: Inflammatory disease of the 3rd phalanx (P3)
 1. Most commonly noninfectious but may be infectious because of trauma or subsolar abscesses
 2. Often seen in concurrently with laminitis
 3. Radiographic findings
 a. Irregularity of the solar margin
 b. Widening of the vascular channels peripherally
 c. If infectious focal area of geographic lysis of P3
 B. Laminitis. Radiographic findings include the following (Figure 5-7):
 1. Palmar or plantar rotation of the 3rd phalanx relative to the dorsal hoof wall
 2. Thickening of the dorsal hoof wall
 3. Decreased thickness of the sole
 4. Remodeling of the toe
 5. Solar margin fractures may be present
 C. Fractures: Lucency in the 3rd phalanx. Named as type I-VII fractures

II. Navicular bone
 A. Navicular degeneration: Radiographic findings may not correlate with clinical signs. Radiographic findings include the following (Figure 5-8):
 1. Erosive lesions of the flexor cortex
 2. Cystic lesions within the body of the navicular bone
 3. Sclerosis of the medullary cavity, with loss of corticomedullary definition
 4. An increase in number, size, and shape of synovial invaginations
 5. Fractures and avulsions of the distal flexor border of the navicular bone (attachment site of the impar ligament)
 6. Osteophyte or enthesophyte production and remodeling at the proximal border and extremities of the bone
 7. Mineralization of the distal sesmoidian (impar) ligament
 B. Navicular osteomyelitis: Usually secondary to a penetrating wound. Radiographic findings include sclerosis and lysis of the navicular bone
 C. Navicular fractures: Improper packing of the sulci of the feet can create artifacts that resemble fractures

III. Degenerative joint disease
 A. Common locations
 1. Tarsus: Distal intertarsal and tarsometatarsal most common
 2. Carpus: Antebrachiocarpal and middle carpal most common

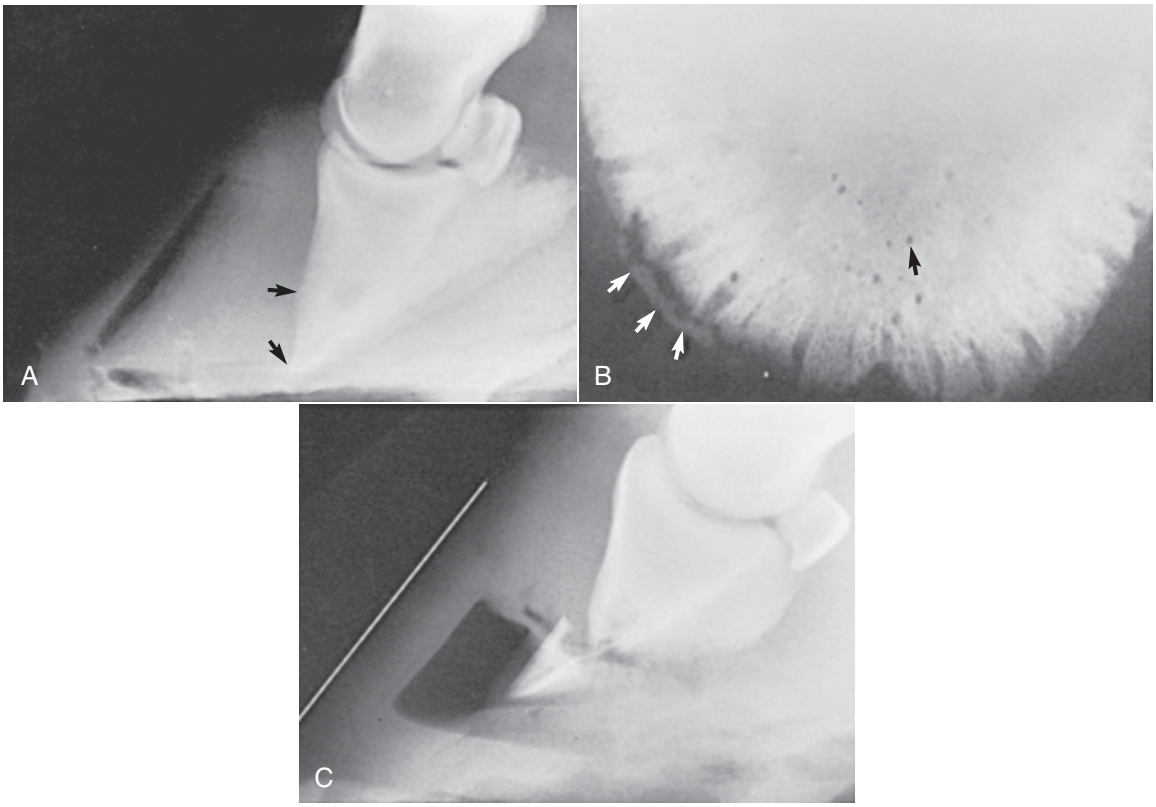


Figure 5-7 **A,** Severe palmar deviation-rotation of P3 resulting from chronic laminitis. Gas is seen between the hoof wall and the soft tissues of the corium. Indistinct dorsal surface *(solid arrow)* and dorsal angulation ("ski tip" appearance) of the toe of P3 *(open arrow)* are additional changes seen in chronic laminitis. **B,** Pathologic type VI fracture of P3 caused by laminitis. Thin bone fragment is separated from the solar margin *(white arrows).* Punctate radiolucent defects *(black arrow)* are enlarged vascular channels viewed end-on. **C,** Larger fracture of the toe with concurrent palmar deviation-rotation. The large accumulation of gas between the hoof wall and the laminar corium is most likely caused by a concurrent subsolar abscess and septic osteitis. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

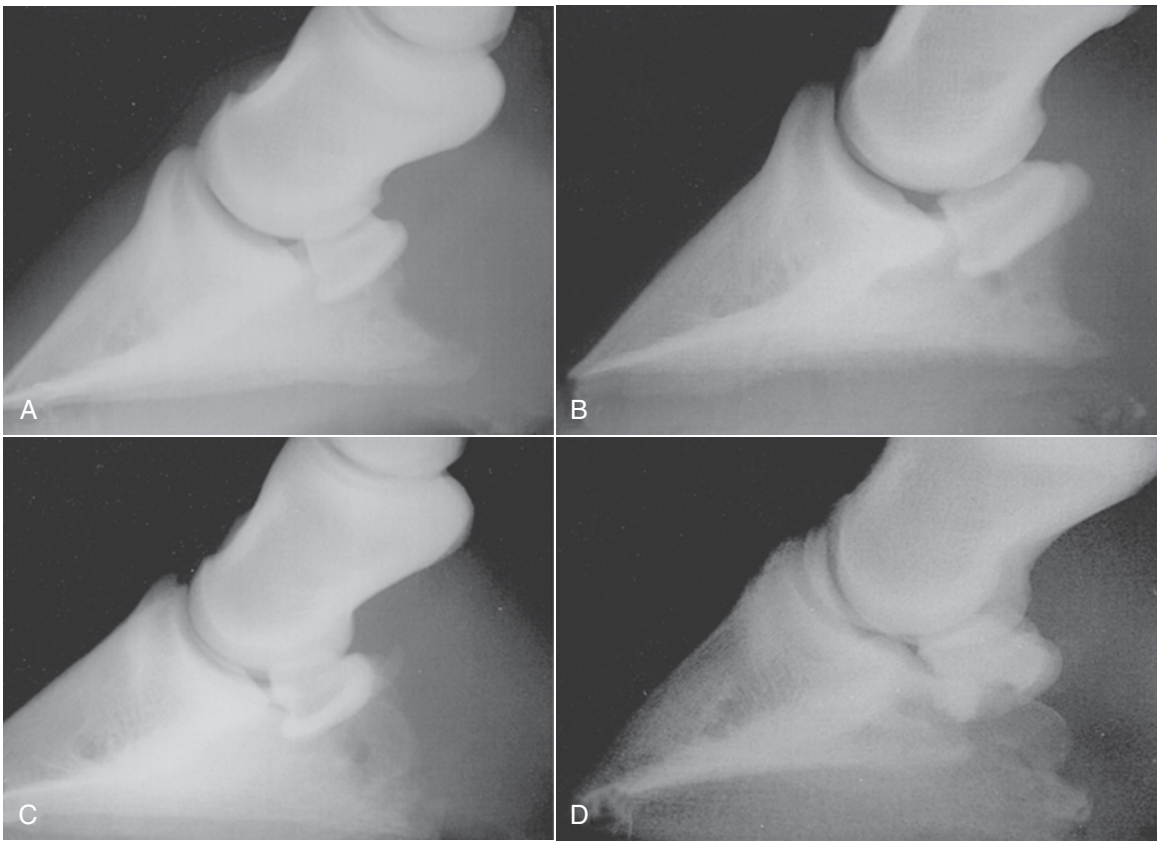


Figure 5-8 Lateral views of the navicular bone. **A,** Normal navicular bone. **B,** Proximal elongation caused by remodeling. **C,** Enthesophyte (spur) on proximal border. **D,** Flexor cortex lysis. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

3. Proximal and distal interphalangeal joints
4. Metacarpal-tarsal phalangeal joints

B. Radiographic findings
1. Increased synovial mass or intraarticular swelling
2. Decreased joint space width
3. Periarticular osteophyte formation
4. Enthesopathy: New bone at soft tissue attachment sites
5. Subchondral bone sclerosis
6. Subchondral cystic changes in severe cases
7. Mineralization of soft tissues: Intraarticular or periarticular

IV. Osteochondrosis or osseous cystlike lesions
A. Common locations
1. Distal intermediate ridge of the tibia (DIRT) lesions
2. Femoral condyles and trochlear ridges
3. Trochlear ridges of the tarsus
4. Metocarpophalangeal joint: Sagittal ridge, distal condyle, proximal 1st phalanx

B. Radiographic findings
1. Subchondral bone lucency or flattening with adjacent sclerosis
2. Defect or irregularity in the subchondral bone
3. Osseous fragment adjacent to the subchondral defect or within the joint
4. Cystlike lesion: Oval area of radiolucency in the subchondral bone

V. Fractures can occur anywhere. Common locations include the following:
A. Carpus: 3rd carpal, radial and intermediate carpal bones, distal radius
B. Comminuted fractures of the 2nd phalanx
C. 2nd to 4th metacarpal and metatarsal bones: Often distal third of splints

VI. Sequestra: Avascular piece of bone secondary to trauma. Radiographic findings include the following:
A. Sharply marginated, sclerotic bone fragment
B. Fragment is separated from the parent bone
C. A draining tract may be present

VII. Angular limb deformity: Carpal valgus most common. Radiographic findings include the following:
A. Physitis: Irregularity and asymmetric widening of the physis
B. Wedging of the distal radial epiphysis
C. Incomplete ossification of the cuboidal bones of the carpus (bones appear small and round)

VIII. Septic arthritis-physitis: Usually hematogenous spread in foals with failure of passive transfer; penetrating wounds in adult horses
A. Radiographic findings with septic arthritis
1. Joint effusion
2. Subchondral bone lysis-sclerosis
3. Multiple joints affected in foals

B. Radiographic findings with septic physitis:
1. Soft tissue swelling centered at the physis
2. Widening-lysis and irregularity of the physis with adjacent sclerosis

ULTRASOUND

I. Basic principles
 A. Creation of sound wave: Diagnostic ultrasound ranges from 2 to 15 MHz; piezoelectric crystal in transducer produces sound waves
 B. Interaction of sound and tissue
 1. Attenuation: Progressive weakening of sound as it travels through tissue
 a. Absorption
 b. Scatter
 c. Reflection
 2. Acoustic impedance: Product of tissue density and velocity of sound. Tissue density differences of tissue results in reflection of sound wave
 C. Image display
 1. B-mode (brightness mode): Real-time imaging with brightness of dot on screen dependent on the amplitude of the returning echo
 2. M-mode (motion mode): Represents motion over a specific time; used for cardiac imaging
 D. Image controls
 1. Image depth
 2. Gain-time gain compensation. Near and far gain
 3. Focal zone
 E. Transducers. Frequency: The higher the frequency, the better the image spatial resolution, but the more limited the depth penetration

II. Normal imaging
 A. Echogenicity: Relative term dependent on intensity of reflected sound
 1. Anechoic: Black, lacking echoes
 2. Echogenic: Gray to white
 3. Hyperechoic: Higher level of echogenicity (brighter) than surrounding structures
 4. Hypoechoic: Lower level of echogenicity (darker) than surrounding structures
 5. Organ echogenicity (from most echogenic to least)
 a. Bone, gas, organ margins
 b. Renal sinus
 c. Prostate
 d. Spleen
 e. Fat
 f. Liver
 g. Renal cortex
 h. Renal medulla
 i. Bile, urine
 B. Artifacts
 1. Acoustic shadowing: Absence of echo signal deep to a strongly reflective (gas) or absorptive (bone) interface. Cannot use ultrasound through gas or bone
 2. Acoustic (far wall) enhancement: Sound beam travels through tissue with no interfaces (such as a fluid-filled structure); stronger echoes in tissue interfaces deep to the fluid-filled structure
 3. Mirror image: Altered paths of reflected sound, creating the illusion of anatomic structures in areas where they are not actually located (e.g., liver appearing on the thoracic side of the diaphragm)

III. Abdomen: Used in conjunction with radiographs
 A. General abdomen: Fluid, carcinomatosis, lymphadenopathy, hernias
 B. Liver
 1. Normal: Uniform echogenicity and echotexture; can see hepatic veins and portal veins; sharp, tapered margin
 2. Focal disease: Can tell solid from cystic lesions (neoplasia, granuloma, abscess, hematoma, cyst)
 3. Diffuse disease: May be increased or decreased in echogenicity with rounding of the hepatic margins
 a. Increased echogenicity: Metabolic (diabetes, lipidosis), endocrine (steroid hepatopathy, Cushing disease or iatrogenic), diffuse neoplasia (lymphoma), cirrhosis, chronic hepatitis
 b. Decreased echogenicity: Diffuse neoplasia (lymphoma), inflammatory or infectious (acute hepatitis), passive congestion (concurrent hepatic vein enlargement)
 4. Multifocal disease: Nodular regeneration, metastatic neoplasia, multifocal abscesses, or granulomas
 5. Gallbladder: Cholelithiasis, mucocele, cholecystitis
 6. Portosystemic shunts can be identified: Intrahepatic and extrahepatic
 C. Spleen
 1. Normal: Uniform echogenicity and echotexture; can see splenic veins
 2. Focal disease: Can tell solid from cystic lesions (neoplasia, granuloma, abscess, hematoma, cyst)
 3. Diffuse disease: May be increased or decreased in echogenicity with rounding of the splenic margins
 a. Anesthetics
 b. Neoplasia
 c. Infection
 d. Immune-mediated disease
 e. Vascular stasis
 f. Extramedullary hematopoiesis
 g. Torsion
 h. Chronic hemolytic anemia
 i. Parasitic infections
 4. Multifocal disease: Nodular regeneration, metastatic neoplasia, multifocal abscesses, or granulomas
 D. Kidneys
 1. Normal: Measurements in dogs are best taken off the VD radiograph compared with L2; on ultrasonography should be smooth in contour with good corticomedullary definition
 2. Abnormal
 a. Diffuse parenchymal disease: Increased cortical echogenicity
 (1) Glomerular and interstitial nephritis
 (2) Acute tubular necrosis

(3) Toxic
(4) Ethylene glycol toxicosis
(5) End-stage renal disease (concurrent decreased corticomedullary definition)
(6) Renal dysplasia
(7) Cats: It may be normal to have increased echogenicity; feline infectious peritonitis (FIP) and diffuse neoplasia (lymphoma) can also cause increased echogenicity

b. Diffuse parenchymal disease: Decreased cortical echogenicity. Diffuse neoplasia, lymphoma.
c. Focal disease
(1) Renal cysts: Solitary or multiple well-circumscribed, fluid-filled
(2) Renal neoplasia: Variable in size and echogenicity
(3) Renal infarcts: Chronic, hyperechoic wedge-shaped at periphery
(4) Renal mineralization. Nephrocalcinosis: Hyperechoic, acoustic shadowing
d. Collecting system: The normal renal pelvis and ureters should not be seen
(1) Pelvic dilation
(a) Mild: Infection or obstruction
(b) Moderate to severe: Obstruction
(2) Hydroureter (dilation of the ureter)
(a) Ectopic ureters
(b) Obstruction: Calculi, stricture or mass
(c) Calculi: Hyperechoic with distal acoustic shadowing

E. Bladder
1. Normal: The bladder should be examined when distended; otherwise, the bladder wall thickness is difficult to interpret
2. Abnormal
a. Urinary calculi: Hyperechoic with distal acoustic shadowing; settles to the dependent part of the bladder
b. Bladder neoplasia: Thickening and irregularity of the wall
c. Cystitis: Mild thickening of the bladder wall (usually at the cranioventral margin)

F. GI
1. Normal: The normal wall thickness of the stomach and small intestine is less than 5 mm in dogs and less than 3.5 mm in cats; the colon is less than 1.5 mm in both dogs and cats
2. Mural disease: Loss of wall layering and increased thickness; often concurrent lymphadenopathy. Differentials include neoplasia (lymphoma and adenocarcinoma most common), granulomatous disease, inflammatory bowel disease
3. Luminal disease: Foreign bodies (FBs), linear FBs
a. Abnormal luminal contents (often shadow); if obstructing bowel orad to the lesion will be distended
b. Linear FB: Placation or bunching of the bowel with a linear structure in the lumen
4. Intussusception: Multilayered, concentric rings (bowel in bowel)
5. Ileus: Functional disease will result in loss of normal bowel motility (normally see four to five peristaltic contractions per minute)

G. Reproductive
1. Ovaries and uterus
a. Cystic ovarian disease: Variable size and number of cysts within the ovary
b. Ovarian neoplasia: Variable echogenicity mass
c. Pyometra: Uterine enlargement with variable echogenicity to the fluid contents
d. Pregnancy — 21 to 30 days after the last breeding is the easiest time to recognize pregnancy; can't count fetal number accurately with US
2. Prostate and testes
a. Benign prostatic hyperplasia: Uniform, symmetric enlargement; smooth margins; variable echogenicity
b. Prostatitis: Symmetrical or asymmetrical enlargement; heterogenous, mixed pattern of varying echogenicity
c. Prostatic neoplasia: Complex echogenicity; variable enlargement and irregularity of margins; may have mineralization
d. Prostatic cyst or paraprostatic cyst: Fluid-filled structure within or adjacent to prostate
e. Testicular neoplasia: Variable size and echogenicity

IV. Thorax (cardiac). Used in conjunction with radiographs
A. Radiographs are best for determining whether left-sided cardiac failure is present; pulmonary venous congestion and cardiogenic edema
B. Uses
1. Congenital diseases
a. PDA
b. Pulmonic and aortic stenosis
c. Mitral and tricuspid dysplasia
d. Ventricular and atrial septal defects
e. Tetrology of Fallot
2. Acquired diseases
a. Mitral and tricuspid insufficiency (valvular degeneration): Abnormal valves with regurgitation on Doppler evaluation
b. Dilated cardiomyopathy: Decreased fractional shortening
c. Hypertrophic cardiomyopathy: Thickening of ventricular wall
d. Restrictive or unclassified cardiomyopathy: Echo findings variable
e. Endocarditis: Very thickened irregular valve leaflets
f. Pericardial disease: Fluid around the heart

V. Thorax (noncardiac). Used in conjunction with radiographs. Cannot ultrasound through lung
A. Pleural disease: Fluid or masses; guide thoracocentesis, fine needle aspiration
B. Mediastinal disease: Most commonly mediastinal lymphadenopathy
C. Pulmonary disease: Only if disease is adjacent to thoracic wall

1. Masses: Neoplasia, granuloma, abscess, cyst
2. Diffuse parenchymal diseases: Pneumonia or neoplasia

D. Thoracic wall: Masses, foreign bodies

VI. Musculoskeletal

A. Small animal

1. Tendons: Biceps and calcanean tendons; compare with other side if normal (echogenicity, measurements, fluid within sheath)
 a. Normal: Tendon is hyperechoic with linear fiber pattern on longitudinal scan
 b. Abnormal: Loss of linear fiber pattern with increased thickness and surrounding fluid
2. Foreign bodies: Hyperechoic, acoustic shadowing, with abnormalities of surrounding tissue

B. Large animal

1. Uses: Most common is tendon and ligaments of the extremities. Normal tendon is hyperechoic with linear fiber pattern on longitudinal scan
2. Abnormal
 a. Core lesions: Focal hypoechoic region in tendon
 b. Diffuse disease: Loss of fiber pattern with decrease in overall tendon echogenicity and increase in tendon thickness
 c. Fluid in tendon sheath: Small amount is normal

VII. Other

A. Pancreas

1. Normal: Uniform in echogenicity, similar to surrounding mesentery
2. Abnormal
 a. Pancreatitis: In dogs, enlarged, irregular, hypoechoic pancreas with hyperechogenicity of the surrounding mesentery; thickening of the wall of the stomach, duodenum, and transverse colon
 b. Pancreatic neoplasia: Focal mass or may see more diffuse disease if carcinomatosis is present

B. Adrenal

1. Normal: Less than 7 mm thick in dogs, less than 4 mm thick in cats
2. Abnormal
 a. Pituitary dependent hyperadrenocorticism: Normal to bilateral, mild adrenal enlargement
 b. Nodules or masses
 (1) Variable in size and echogenicity
 (2) Primary adrenal tumors or metastatic disease

C. Eye: Retinal detachment, masses, retrobulbar disease

Supplemental Reading

Burk RL, Feeney DA. *Small Animal Radiology and Ultrasound*, 3rd ed. Philadelphia, 2003, Saunders.

Nyland TG, Mattoon JS. *Small Animal Diagnostic Ultrasound,* 2nd ed. Philadelphia, 2002, Saunders.

Owens JM, Biery DN. *Radiographic Interpretation for the Small Animal Clinician.* Baltimore, 1999, Williams & Wilkins.

Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 4th ed. Philadelphia, 2007, Saunders.

Food Safety

CHAPTER 6

H. Fred Troutt

UNITED STATES GOVERNMENTAL AGENCIES AND REGULATIONS SIGNIFICANTLY INVOLVED IN FOOD SAFETY OF ANIMAL PRODUCTS

I. Food and Drug Administration (FDA), Department of Health and Human Services (DHHS)
 A. Regulation: Title 21, Food and Drugs, Control of Communicable Diseases
 1. Regulates domestic and imported food, except meat, poultry, and processed egg products, to ensure safety and proper labeling
 2. Defines milk, milk products, and cream products
 a. Defines *pasteurization* and specifies pasteurization time temperature relationship as follows:

Temperature	Time
145° F	30 minutes
161° F	15 seconds
191° F	1 second
204° F	0.05 seconds
212° F	0.01 seconds

 b. Defines *ultra-pasteurization*: A product thermally processed at or above 280° F for at least 2 seconds either before or after packaging to produce a product with an extended shelf life under refrigeration
 B. FDA, US DHHS Federal Food, Drug and Cosmetic Act
 1. Provides for definition and standards for food
 2. What constitutes adulteration of food (to cause risk of injury to health)?
 a. Any poisonous or deleterious substance that can cause injury to health
 b. Any added poisonous or deleterious substance
 c. Pesticide: Chemical or residue, any food additive, or a new animal drug, all as defined by the Act
 d. Whole or in part filthy, putrid, or decomposed substance
 e. Prepared, packed, or held under unsanitary conditions
 f. Product of diseased animal or an animal that has died otherwise than by slaughter
 g. Container in part or whole is made from poisonous or deleterious substance
 h. Intentionally irradiated outside of regulations governing irradiation of food
 i. Concealment of damage or inferiority of product
 j. Valuable constituent has been omitted from the product; damage has been concealed
 k. Substance added to increase bulk, reduce quality, or make it appear better or greater value than it is

II. U.S. Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS)
 A. Agency works to ensure meat, poultry, and some eggs and egg products sold in interstate or foreign trade are safe and properly labeled
 B. Authorization under Meat Inspection Act of 1906 providing for the following:
 1. Inspection of meat and meat food products
 a. Examination of animals before slaughter
 b. Diseased animals slaughtered separately and carcasses examined
 c. Humane methods of slaughter
 2. Postmortem examination of carcasses and marking or labeling of carcasses
 a. Destruction of condemned carcasses
 b. Reinspection
 3. Examination of carcasses brought into slaughter or packing establishments and of meat food products issued from and returned to establishments; conditions for reentry
 4. Inspectors of meat food products
 a. Marks of inspection
 b. Destruction of products
 c. Products for export
 C. Adopted 1996 The Final Rule on Pathogen Reduction and Hazard Analysis and Critical Control Point (HACCP) Systems
 1. HACCP
 a. FSIS published in 1996
 b. Process control system, plan
 c. Required of all federally inspected meat and poultry plants
 d. Designed to control, eliminate, reduce hazards adulterating food products
 e. Goal: Reducing or eliminating contamination of meat and poultry by pathogenic bacteria
 f. Components: Conduct hazard analysis
 (1) Threats to human health by way of meat and poultry: Biological (microbiological), chemical, or physical

(2) Biological hazards: Living organisms that make food unsafe
(a) Biological: Bacterial, parasitical or viral
(b) Major bacterial pathogens
i. *Salmonella* spp
ii. *Campylobacter jejuni*
iii. *Escherichia coli* 0157:H7
iv. *Listeria monocytogenes*
v. *Clostridium botulinum*
vi. *Staphylococcus aureus*
vii. *Yersinia enterocolitica*
(3) Chemical hazards: Naturally occurring or added during processing
(a) Natural: Constituents of food
i. Aflatoxins
ii. Mycotoxins
iii. Shellfish toxins
(b) Added: Broad range; examples follow:
i. Components of animal feed
ii. Animal drugs
iii. Pesticides
iv. Lubricants
v. Cleaners
vi. Paints
vii. Coatings
(4) Physical hazards
(a) Unexpected in the food
(b) May cause illness if consumed
(c) Glass, metal, or plastic (rebroken needles)

2. Identify *critical control points* (CCP). Point, step, or procedure in the process where a control can be applied
a. Preventing, eliminating, or reducing a food safety hazard to an acceptable level
b. Examples include the following:
(1) Chilling temperatures (minimize microbial growth)
(2) Cooking at specific temperatures and times
(3) Adjustment of pH or water activity
(4) Proper sealing of cans, etc.
(5) Slaughter interventions to reduce alleviate contamination
3. Establish *critical limits*
a. Boundaries of safety for measures put in place at CCPs
b. Maximum or minimum value to control, eliminate, or reduce the hazard at a CCP
c. Usually a reading or observation such as temperature, pH, salt concentration
4. Establish monitoring procedures
a. Activities and procedures done by personnel or mechanical means; measure process at a CCP
b. Create record for future use; continuous monitoring is preferred
5. Establish corrective actions
a. Action taken when monitoring shows a deviation from the critical limit
b. Features include the following:
(1) Has cause of deviation been identified and eliminated?
(2) Will the CCP be under control after corrective action?
(3) Have measures to prevent recurrence of deviation been established?
(4) Do corrective action procedures ensure that no product is injurious to health or otherwise adulterated because of the deviation and product enters commerce?
6. Establish record-keeping procedures: Records must document HACCP system and be an essential feature of HACCP system
7. Establish verification procedures
a. Validation of initial plan, for example, through microbial or chemical testing
b. Ongoing verification: Procedures that ensure that HACCP process is working day to day
c. Reassessment: Overall review of plan periodically (annually) or after changes are made

FOODBORNE ILLNESS (DISEASE)

I. General information
A. Cause: Consumption of contaminated food or beverages
1. Bacteria, viruses, and parasites
2. Toxins or chemicals
B. More than 250 food-borne diseases
C. United States Centers for Disease Control and Prevention (CDC)
1. Estimates 76 million cases of food-borne disease
a. 325,000 hospitalizations
b. 5,000 deaths
2. Most susceptible human populations
a. Very young and very old
b. Immunosuppressed
c. Healthy people exposed to high dosage of an infectious agent
3. Food-borne disease outbreak (FBDO)
a. Two or more people ill after consuming a common food
b. Epidemiologic investigation indicates food as source of illness
c. May be local or widespread (multiple states or national)
d. Case definition developed on a disease-by–disease basis
(1) Clinical description: Incubation period, signs and symptoms, illness length, response to treatment
(2) Diagnostic laboratory and epidemiologic criteria, for example, positive fecal culture; pathogen isolation from suspect food contaminated during processing or and distribution
e. Many food-born pathogens are zoonotic via ingestion of contaminated foods or food products

D. Food type most associated with food-borne illness
 1. Raw (undercooked) foods of animal origin
 a. Meat and poultry (ground meats)
 b. Raw eggs
 c. Unpasteurized milk
 d. Raw shellfish or fish
 2. Co-mingled product from numerous animals, such as pooled raw eggs, bulk raw milk, ground beef (hamburger)
 a. Pathogen in one source contaminates all
 b. Meat in a hamburger paddy may originate from trim of many animals (i.e., more than 40)
 c. Product washing with pathogen-contaminated water

E. Most commonly recognized food-borne infections caused by the following:
 1. Bacteria
 a. *Campylobacter* spp.
 b. *Salmonella* spp.
 c. *Escherichia coli* 0157:H7
 2. Viruses: Calicivirus (Norwalk and Norwalk-like viruses)

F. Food-borne infections (see subsequent sections). Cause: Pathogens that replicate in host after ingestion (e.g. *Salmonella* spp.)

G. Food-borne intoxication (see subsequent sections): Clinical and pathologic changes caused by the ingestion of preformed toxins (e.g., staphylococcal toxins; botulinum toxin)

II. Common food-borne *bacterial* pathogens

A. *Campylobacter*: Most common cause of human diarrheal disease in United States and worldwide (gram-negative)
 1. *C. jejuni* and *C. coli* (ubiquitous)
 2. Animal pathogens (abortion, mastitis, diarrhea in dogs, cats)
 3. Zoonotic pathogens (animal reservoirs)
 a. Commensal in the gastrointestinal (GI) tract of cattle, swine, sheep, goats, poultry, rodents, dogs, and cats
 (1) Fecal contamination
 (2) Unpasteurized dairy products
 (3) Uncooked foods via cross contamination from contaminated meat and poultry
 b. Human food-borne illness: Fever, diarrhea (often bloody), abdominal pain/cramps (vomiting rarely marked)
 (1) Incubation period: Usually 2-5 days (may extend to 10 days)
 (2) Confirmation: Isolation of organism from 2 or more ill people or isolation from implicated food
 (3) Risk of antibiotic resistant campylobacter
 (4) Complications: Rare, but can include arthritis, meningitis, recurrent colitis, chole cystitis and Guillain-Barre syndrome
 (5) General control
 (a) Husbandry practices and enhanced livestock hygiene
 (b) Hygienic slaughter and processing
 (c) Personal sanitation – handwashing; "petting zoos" are a risk
 (d) Thorough cooking meat and poultry
 (e) Proper storage and refrigeration

B. *Salmonella* spp. (gram-negative)
 1. Greater than 2000 serovars, highly ubiquitous
 2. Infects companion and agricultural animals, poultry, birds, rodents, and reptiles
 3. Host and nonhost adapted
 4. Host adapted
 a. *S. typhi* cause of typhoid fever in humans
 (1) Human carrier: Food and water contaminated by feces from carrier
 (2) Systemic infection (bacteremia)
 (3) Incubation period: 7 to 21 days; slow onset of illness, fever (103 to 104° F) during first 1 to 2 weeks, rash
 b. *S. pullorum*: Poultry pathogen, non-zoonotic
 c. *S. gallinarum*: Poultry pathogen, non-zoonotic
 5. Nontyphoid serovars (non-host adapted)
 a. Most *Salmonella* serovars; zoonotic pathogen
 b. Widespread in intestines of birds, mammals, and reptiles
 (1) Fecal contamination of raw meat (ground beef), poultry, eggs, unpasteurized milk or dairy products, seafood
 (2) Contaminated water
 c. Human food-borne illness
 (1) Two to four million cases per year in United States
 (2) Onset dramatic
 (3) Incubation period: 6 to 48 hours
 (4) Very young, very old, and immunosuppressed increasingly susceptible
 (5) Nausea, severe diarrhea, vomiting, headaches, chills, myalgia, and low fever
 (6) Invasive organism, enterocolitis
 (7) Bacteremia
 (8) Chronic complications
 d. *S. enteritidis* most prevalent cause of salmonella outbreaks in United States. Consumption of raw or inadequately cooked whole-shell eggs
 e. Confirmation: Isolation of organism from two or more affected people or isolation from implicated food
 6. General control: As with *Campylobacter*

C. *E. coli* 0157:H7 (gram-negative), (*E. coli* 0157:H7; VTEC, Verotoxin *E. coli*; EHEC, enterohemorrhagic *E. coli*)
 1. Zoonotic pathogen: Occasional resident in intestine of wild and domestic animals, especially cattle (prominent reservoir for human infection). Animals are usually asymptomatic
 2. Disease in humans: Acute colitis, severe abdominal pain (cramping), profuse watery to bloody diarrhea, occasional vomiting, and low-grade fever or no fever
 a. Very young and elderly may develop hemorrhagic uremic syndrome (HUS) with possible subsequent renal failure

b. Elderly, thrombocytopenic purpura (TPP) with upwards of a 50% mortality rate
c. Once considered a rare or unusual condition: Increasing occurrences
d. Verotoxins, also called *Shiga-like toxins,* likely cause hemorrhage associated with diarrhea
e. Incubation period: 3 to 4 days (1 to 10 days)
3. Food sources: Undercooked ground beef (hamburger), beef, cheese curds, unpasteurized apple juice, unpasteurized milk, fresh produce including lettuce, alfalfa sprouts, radish sprouts, contaminated water
4. Confirmation: Isolation of *E. coli* 0157:H7 or other Shiga-like toxin producing *E. coli* from two or more ill people or isolation of *E. coli* 0157:H7 or other Shiga-like toxin producing *E. coli* from suspect food or water

D. Other *E. coli* causing food-borne illness
1. Enterotoxigenic *E. coli* (ETEC) (gram-negative)
a. "Traveler's diarrhea"
b. Infants in underdeveloped countries
c. Sewage contaminated water
d. Infected or contaminated food handlers
2. Enteropathogenic *E. coli* (EPEC) (gram-negative)
a. "Infantile" diarrhea; sporadic outbreaks
b. Sources: Humans, cattle, and swine can be infected
c. Can be zoonotic
d. Watery to bloody diarrhea
e. Sources: Any food exposed to feces
3. Enteroinvasine *E. coli* (EIEC) (gram-negative)
a. Dysentery-like illness; blood and mucus in stools ("bacillary dysentery"): Abdominal pain, vomiting, diarrhea, fever, chills, malaise. HUS may occur in young children
b. Uncommon
c. All people seem susceptible
d. Food sources: Any food or water contaminated with human feces; hamburger, unpasteurized milk
e. Human-to-human transmission
f. Confirmation: May be difficult (low infective dose); as with other *E. coli*

III. Other important food-borne bacterial pathogens
A. *Clostridium botulinum* (gram-positive)
1. Spore-forming organism producing potent neurotoxin
2. Seven types of botulism based on toxin types: A, B, C, D, E, F, and G
a. A, B, E, and F: Human botulism
b. C and D: Animal botulism
3. Organism and spores widely distributed in nature; soil, intestinal tracts of mammals and fish
4. Disease
a. Food-borne botulism: An intoxication from ingestion of foods containing *C. botulinum* neurotoxin
(1) Toxin: Heat-labile, destroyed at 80° C for 10 minutes or longer
(2) Onset of symptoms is usually 12 to 36 hours (2 hours to 14 days)
(3) Nausea, vomiting followed by variety of neurologic signs, including vertigo, muscle weakness, difficulty swallowing, blurred vision, diarrhea (later constipation), abdominal pain
(4) Food sources: Home canned foods; commercial meat products, sausages, canned vegetables, canned seafood
(5) Confirmation: Detection of toxin in patient serum, stool, gastric contents or suspect food, or isolation of *C. botulinum* from stool or intestine toxin detection is by injection of food extract into positively immunized mice (mouse neutralization test)
b. Infant botulism
(1) Affects infants under 1 year of age
(2) Food source: Honey
(3) Initial sign is usually constipation followed by poor feeding, lethargy, altered cry, loss of head control
5. High mortality without rapid intervention
6. Control: Prevention of toxin production
a. Stringent temperature controls at processing
b. Minimum acidity at pH 4.6
c. Specified salt (NaC1) content
d. Specified water activity
e. Use of regulated amounts of nitrite

B. *Clostridium perfringens* (gram-positive)
1. Produces wide array of toxins
2. *C. perfringens* type A causes food-borne enteritis in humans; major food-borne illness
3. Spores persist in soil and areas where there is human or animal fecal contamination
4. In humans common source of infection is via fecal contamination; often associated with group catering
5. Also zoonotic transmission. Contaminated, poorly cooked (heated) pork, beef, and poultry products; pets may harbor *C. perfringens*
6. Incubation: 6 to 24 hours; enterotoxin triggers diarrhea
7. Illness: Severe abdominal pain or cramps, diarrhea; course approximately 24 hours. Symptoms may persist for 1 to 2 weeks in elderly or infirm patients
8. Confirmation: Bacteriologic isolation of large numbers from patient feces or suspect foods; identification of entertoxin
9. Prevention: Food hygiene, proper cooling of foods, thorough cooking

C. *Listeria monocytogenes* (gram-positive)
1. Widespread organism, intestine of humans, other mammals (domestic and wild), birds and possibly fish (zoonotic agent)
a. Sheep are a major reservoir
b. "Circling disease" in ruminants
2. Hardy organism: Can grow over wide range of temperatures and pH ranges
a. −1.5 to 45 to 50° C (survives freezing)
b. pH range for survival is 4.3 to 9.6
3. Unlikely to survive normal commercial pasteurization temperature

4. Illness
 a. Incubation: 2 to 6 weeks (for meningitis, etc.)
 b. Nausea, vomiting, and diarrhea may be only signs or may precede more serious signs and symptoms
 c. Fever (persistent) and influenza-like signs usually precede serious manifestations
 d. Serious manifestation: Septicemia, meningitis, encephalitis, meningoencephalitis, cervical or uterine infections leading to second- or third- trimester abortion in pregnant women
5. Foods associated: Raw milk, cheese (especially soft ripened), ice cream, fermented raw meat sausages, raw meats (all types), raw and cooked poultry, smoked and raw fish, raw vegetables (wide variety)
6. Confirmation
 a. Listeriosis: Culture of organism from blood, cerebrospinal fluid, feces (difficult)
 b. Food: Isolation of the organism with highly selective media
7. Susceptible populations
 a. Pregnant women
 b. Immunocompromised people (drugs, AIDS)
 c. Cancer patients, especially leukemia patients
 d. Normal people with large dose of organism

D. *Yersinia enterocolitica* (and *Yersinia pseudotuberculosis*) (gram-negative)
1. Both enteropathogenic species but contain nonpathogenic strains
2. Not inhabitant of human normal intestinal flora
3. Zoonotic organism; swine principal reservoir; tongue, pharynx, tonsils, cecal contents, and feces
4. Illness: Yersiniosis
 a. Incubation period: 4 to 6 days (1 to 10 days)
 b. Gastroenteritis: Fever, vomiting, diarrhea, marked abdominal pain (mimics appendicitis and mesenteric lymph adenitis)
 c. Causes infection of wounds, joints, and urinary tract
5. Complications
 a. Unnecessary appendectomies
 b. Post-enteritis arthritis (reactive arthritis)
6. Food sources: Contaminated or under cooked pork, lamb, beef (processed meats), raw milk, raw fish, and oysters. Contaminated water
7. Confirmation: Isolation from two or more affected patients or from suspect food or water
8. Prevention
 a. Use of uncontaminated raw ingredients
 b. Proper food preparation
 c. Thorough sanitation and hygiene of processing equipment

E. *Staphylococcus aureus* (gram-positive)
1. Staphylococcal food poisoning caused by enterotoxin produced by same strains of *S. aureus*, one of leading causes of food poisoning worldwide
2. Food intoxication
3. Illness
 a. Depends on amount of toxin ingested, susceptibility to the toxin, and health of the individual
 b. Commonly, nausea, vomiting, abdominal pain and cramping, prostration, muscle cramping
 c. Incubation: 2 to 4 hours (0.5 to 8 hours); duration 2 to 3 days
 d. Enterotoxins (A, B, C, D, E, G, H, and I) emetic causes of *S. aureus* food poisoning
 (1) Heat resistant
 (2) Produces in a variety of conditions for growth
 e. Possible zoonotic agent
 f. Food sources
 (1) Foods requiring much handling; maintained at slightly elevated temperatures post-preparation
 (2) Meat products, poultry, and egg products
 (3) Salads: egg, tuna potato, and others
 (4) Cream-filled pastries
 (5) Raw milk
 (6) Canned mushrooms
 g. Main staphylococci sources: Humans and animals; food handlers are usual source of food contamination
 h. Complications: Death is unusual or rare but has occurred in very young, very old, or debilitated people
 i. Confirmation: Isolation of same phage type from stool or vomit from two or more ill people or detection of enterotoxin in suspect food or isolation of large numbers *S. aureus* from suspect food

F. *Bacillus cereus* and other *Bacillus* spp. (gram-positive)
1. Possible zoonotic organism
2. *B. cereus* food poisoning
 a. Diarrheal type caused by a large-molecular-weight (mw) protein, mimics *C. perfringens* food poisoning with watery diarrhea and abdominal pain or cramps
 (1) Incubation: 6 to 15 hours after consumption
 (2) Duration is about 24 hours
 b. Vomiting type caused by a heat-stable peptide mimics *Staphylococcus aureus* food poisoning with nausea and vomiting and occasional diarrhea and abdominal pain
 (1) Incubation: 0.5 to 6 hours
 (2) Duration: 24 hours
 (3) Food source
 (a) Diarrheal type: Undercooked meat, fish, and vegetables; raw milk
 (b) Vomiting type: Rice products, sauces, potato pasta, puddings, etc.
 (4) Confirmation
 (a) Vomiting toxin: Isolation of *B. cereus* from feces of two or more sick people and not from feces of control patients or isolation of large number of organisms from suspect food

(b) Diarrheal toxin: Same criteria as for *B. cereus*: Vomiting toxin and type

G. *Brucella* spp.
1. *B. abortus, B. meliteusis,B. suis*: Natural hosts are cattle, sheep, goats, and swine, respectively
 a. Humans: Accidental host as result of direct contact with infected animals or by consuming contaminated (unpasteurized) dairy products
 b. *B. abortus* first isolated from cattle by Dr. B.L. Bang, Danish veterinarian and physician (1897)
2. Human brucellosis: Serious globally, relatively rare in the United States but may be underdiagnosed
 a. Potentially life-threatening multisystem disease
 b. Signs and symptoms range from influenza-like (fever, headache, back pain, lethargy, or weakness) to infection of the central nervous system (CNS) or endocarditis
 c. Chronic symptoms include recurrent fever, splenomegaly joint pain, pronounced fatigue
 (1) Human-to-human spread is considered rare
 (2) Incubation: Usually greater than 30 days (days to months)
 (3) Confirmation: Two or more sick people and isolation of *Brucella* organisms from culture of blood or bone marrow or 4× elevations in standard agglutination titers (SAT) over several weeks or single SAT 1:160 or greater in patient with suggestive clinical signs and symptoms
 (4) Prevention: Do not consume unpasteurized dairy products; do not handle viscera of wild or domestic animals without appropriate protective gloves

H. *Vibrio cholerae* (gram-negative) causes cholera
1. Incubation: Hours to 5 days
2. Source: Contaminated food or water; disease of poor sanitation with contamination of drinking water; transmitted by shellfish; food prepared with contaminated water; food contaminated by human feces
3. Cholera toxin (choleragen) determinant of virulence
4. Disease, sudden-onset vomiting, "rice-water" profuse diarrhea (painless) as disease progresses; reduced renal function, dehydration and electrolyte inbalances that are life-threatening (death can occur within hours)
5. Confirmation: Isolation of toxigenic organism from feces or vomit of two or more patients or antitoxin antibodies in acute and convalescent sera of unvaccinated patients; isolation of the toxigenic organism from suspect food
6. Control
 a. Supply potable water for drinking and food preparation
 (1) Point source chlorination
 (2) Boiling
 b. Prevent contamination of water made potable
 c. Thorough cooking
 d. Refrigeration where cold chain is available
 e. Handwashing and disinfection
 f. Appropriate sewage disposal/restriction

I. *Vibrio parahaemolyticus* (gram-negative)
1. Widely distributed estuarine and marine environments
2. *V. parahaemolyticus* gastroenteritis
3. Illness: Vomiting, diarrhea, abdominal cramps, fever and chills lasting 2 to 3 days
 a. Incubation: 4 to 96 hours
 b. Toxin thought involved
4. Foods: Raw or undercooked or cooked and recontaminated shell fish and fish
5. Confirmation: Culture of *V. parahaemolyticus* from diarrhea of affected people
6. Numerous marine vibros are associated with food-borne illness

J. *Shigella* spp. (gram-negative): *S. sonnei* most common identified in United States outbreak
1. Illness: Shigellosis (bacillary dysentery)
 a. Highly communicable, few cells (10) will infect
 b. Incubation: 3 days (1 to 7 days)
 c. Abdominal pain and cramps, fever, vomiting, diarrhea with blood, mucus and pus, tenesmus
 d. Interotoxin and *Shiga* toxins from some strains
2. Sources
 a. Variety of food owing to poor personal hygiene by food handlers
 b. Human feces contaminated drinking and food-preparation water
 c. Poor hygiene as in daycare and nursing home facilities
 d. Contaminated fruits, vegetables, meat, poultry, and baking products
3. Confirmation: Isolation of same serotype from two or more ill people or isolation of organism from suspect food or and water.

SELECTED VIRAL FOOD-BORNE DISEASE AGENTS

I. Hepatitis A (HA): Ribonucleic acid (RNA) virus, Picornaviridal family
 A. Illness: Usually mild; sudden fever, nausea, anorexia, abdominal discomfort, and in several days, jaundice
 1. Significant disease in United States
 2. Incubation: 15 to 50 days
 3. Confirmation: Detection of immunoglobulin M antibody to HA virus in sera from two or more affected people consuming suspect food
 B. Source: Ingestion of water or foods contaminated by human feces and not sufficiently cooked; raw shellfish, contaminated fresh fruits and vegetables, fresh frozen foods

II. Hepatitis E (HEV): RNA virus
 A. Illness: As with HA incubation: 40 days (15 to 60 days)

B. Transmission: Ingestion of human feces-contaminated drinking water or food; minimal person-to-person transmission
C. In United States cases, usually history of travels to HEV-endemic areas

III. Rotavirus RNA virus, family Reoviridae
A. Most common cause of severe diarrhea in children; usually self-limiting with mild to pronounced watery diarrhea, vomiting, and low fever
B. Potential for interspecies infection
C. Fecal-to-oral spread (fecal contaminated food and water); person-to-person by contaminated hands
D. Confirmation: Rapid antigen detection of rotavirus in feces; recovery of virus from suspect foods

IV. Calicivirus (Norwalk; Norwalk-like; Norovirus); RNA
A. Illness: Mild, self-limiting with nausea, vomiting, diarrhea, and abdominal pain; headache and low-grade fever may occur
1. Incubation: 24 to 48 hours
2. Duration: 24 to 60 hours
B. Transmission: Fecal-oral route via contaminated water and foods; water most common source of outbreak; infected persons such as food handlers
C. Confirmation: Detection of viral RNA in two or more fecal or vomit specimens by specific polymerase chain reaction (PCR) techniques; two or more stools positive for the virus by commercial enzyme immunoassay procedure
D. Control: Sanitation and hygiene; potable water; personal hygiene

SELECTED PARASITES CAUSING HUMAN FOOD-BORNE ILLNESS

I. *Cryptosporidium parvum*; intracellular protozoa
A. Zoonotic parasite (fecal contamination). Calves likely source of human infection, but *Cryptosporidium* spp. infects cattle, sheep, goats, deer and elk, water fowl, wide range of birds and mammals, including pets
B. Human-to-human (fecal contamination)
C. Cryptosporidiosis (intestinal, tracheal, or pulmonary disease entities). Intestinal: Profuse, watery diarrhea usually (daycare centers); diarrhea may persist for several weeks. AIDS patients (immunocompromised) may retain for life, and disease may contribute to death; nausea, vomiting, abdominal pain, fever, dehydration
D. Source: Contaminated drinking water; contaminated recreational water accidentally swallowed, food or objects contaminated by feces and placed in mouth
E. Confirmation: Acid-fast fecal smears, immunofluorescence microscopy; enzyme immunoassays (commercial test kits)
F. Prevention
1. Sanitation and hygiene
2. Drink only safe (potable) uncontaminated water
3. Avoid swallowing recreational water. *Crytosporidia* is highly resistant to chlorine and iodine

II. Taeniasis (infection with tapeworm): A zoonotic parasitic infection of humans with adult tapeworm *Taenia saginata* (cattle tapeworm) or *Taenia soliuni* (pork tapeworm)
A. Cattle and pigs ingest vegetation contaminated with tapeworm eggs or proglottids
B. In cattle and pigs, larval stages migrate to muscle tissue and develop into cysticeri, which can infect humans when undercooked meat is eaten, causing cysticercosis
C. Cysticercosis
1. *T. saginata* is often asymptomatic to nausea, intestinal discomfort, diarrhea, or constipation; detection of proglattids in feces; rarely causes cysticercosis
2. *T. solium* signs similar to that of *T. saginata* intestinal infection but also causes cysticercosis in a number of organs, including the brain (neurocysticercosis). Neurocysticerosis shows a variety of neurologic signs from apathy or depression to seizures and dimentia
3. Incubation: 5 to 12 weeks
4. Confirmation: Microscopic examination of fecal specimens for eggs and proglottids 3 months after suspect infection; imaging techniques to detect cysticerei
5. Prevention
a. Thorough cooking of meat
b. Freezing meat at −5° C for 4 days
c. Slaughter inspection

III. Trichinellosis (*Trichinella* spp., including spiralis, pseudospiralis, nativa, and nelsoni)
A. Zoonotic food-borne human parasitic disease from eating raw or undercooked meat containing the nematode larvae of *Trichinella* spp.
1. *T. spiralis*: Worldwide carnivores and omnivores, especially domestic swine (pigs acquire through garbage feeding, such as meat scraps, rats, and cannibalism)
2. *T. pseudospiralis*: Worldwide mammals and birds (rare); pathogenic for humans; larvae do not encyst
3. *T. nelsoni*: Equatorial African scavengers and predators
4. *T. nativa*: Artic bears and other Artic wildlife
B. Transmission
1. Domestic cycle (e.g., between pigs) to humans via ingestion of infected raw or undercooked pork
2. Sylvantic cycle (e.g. between wildlife) to humans via ingestion of raw or undercooked wild animal meat
C. Cycle
1. Encysted larvae are ingested, released in the small intestine (SI), invade SI mucosa, become adults; in about a week, females release larvae that migrate to striated muscle and encyst and can remain viable for years
2. Ingestion of encysted larvae maintains cycle; rats and other rodents are responsible for endemic nature
D. Illness: Nausea, vomiting, abdominal discomfort or pain, fever, lethargy followed by headache, fever, cough, muscle and joint pain; cardiac and respiratory symptoms; with severe infection, death.

1. Incubation: 1 to 2 days for abdominal symptoms; others in up to 8 weeks
2. Mild cases: Usually undiagnosed

E. Confirmation: Antibody detection by enzyme immunoassays (EIA); *Trichinella* enzyme-secretary (ES) products; muscle biopsy, microscopy
F. Prevention is by thoroughly cooking meats

IV. Toxoplasmosis
A. *Toxoplasma gondii*, a protozoal parasite of feral and domestic cats capable of infecting a wide range of animals; zoonotic parasite
B. Transmission: Poor sanitation after handling infected cats or litter boxes; eating contaminated raw or undercooked meat, especially beef, pork, lamb, or venison; contaminated food utensils including cutting boards; drinking fecally contaminated water
C. Susceptible population: Healthy people often have few symptoms; pregnant women and immunocompromised individuals (AIDS patients) are very susceptible
D. Cycle: Infected oocysts in feral or domestic cat feces; fecal contamination to intermediate hosts such as swine, sheep, and ingestion of raw or undercooked meat by humans
E. Illness: Variable signs; influenza-like signs lasting a month or more; CNS and ocular toxoplasmosis; intrauterine infection that can cause death or subsequent brain or eye lesions
F. Prevention
1. Food-preparation sanitation and hygiene
2. Thorough cooking of food
3. Steps to prevent person or objects, food contamination by cat feces
4. Potable drinking water

PRION DISEASE

I. Prion: A normal protein when misshaped (misfolding) can be infectious by causing other prions to misfold in a cascade effect subsequently causing disease (transmissible spongiform encephalopathies) (TSEs)
II. Cattle disease: Bovine spongiform encephalopathy (BSE, "mad cow disease"); isolated occurrence in the United States
III. Human disease: Variant Creutzfeldt-Jakob disease (vCJD)
IV. BSE and vCJD thought to be caused by same agent (zoonotic agent)
V. Food Source: meat products or by-products or supplements contaminated by BSE prions (e.g. rendered products)
A. High-risk sources: Affected cattle brains, trigeminal ganglia, skulls, tonsils, spinal cord, dorsal root ganglia, and distal ileum
B. Incubation: Thought to be years
VI. Illness: TSEs (vCJD and BSE) cause severe neurodegenerative brain disease (vCJD depression to eventual dementia and death)
VII. Confirmation: Histologic examination of brain tissue
VIII. Prevention: FDA regulation (1997) prohibits feeding of most mammalian protein to ruminant animals

FOOD-BORNE NATURAL TOXINS

There are a large number of natural toxins including but not limited to:

I. Aflatoxins / Aflatoxicosis; toxins produced by *Aspergillera flavus* and *A. parasiticus*
A. Illness: hepatic diseases —— necrosis, cirrhosis and carcinoma; nontransmissable
B. Illness following ingestion of contaminated food products —— corn; peanuts, cottonseed, milk and tree nuts
C. According to FDA information no outbreaks in humans in United States

II. Mushroom toxins: Categories of toxins.
A. Protoplasmic: General cell destruction to organ failure
B. Neurotoxins: Sweating, depression, hallucinations, seizures coma
C. GI irritant toxins: Sudden onset, transient nausea, vomiting, abdominal pain or cramps, diarrhea
D. Disulfiram-like toxin: Cause no illness unless alcohol consumed within 72 hours after eating mushrooms, a transient acute toxic reaction
1. Illness: Variable
2. Source: Invariably wild mushrooms, including home-canned and frozen; contaminated sauces
3. Confirmation: Recovery and identification of toxin (difficult) from suspect food

III. Pyrrolizidine alkaloids
A. Moderate to severe hepatic damage following acute GI signs such as vomiting, abdominal pain, and development of ascites; fever, icterus; pulmonary disease
B. Source variety of contaminated legumes, cereal grains, houseplant-based remedies, for example
C. Illness, according to FDA "relatively rare" in the United States

IV. Phytohaemagglutinin (a lectin)
A. Red kidney bean toxicity (other beans also)
B. According to FDA, no published reports in the United States; moderate prevalence in United Kingdom
C. Illness: Rapid onset (several hours) with profuse vomiting, diarrhea, etc.; short duration; attack rate is 100%

V. Grayanotoxin
A. Honey intoxication; nectar of rhododendrons causing rapid onset dizziness, weakness, vomiting
B. Illness rarely fatal (FDA), lasts about 24 hours; dizziness, sweating, weakness, nausea and vomiting; low blood pressure, bradycardia with irregular heart rhythm (bradyarrhythmia) to atrioneutricular block
C. Occurs in United States

VI. Fish and shellfish toxins
A. Ciguatera fish poisoning: Tropical and subtropical fish (snappers, jack, barracuda, mackerel) causing a combination of GI, cardiovascular, and neurologic signs and symptoms
1. Result of contamination by dinoflagellate algae
2. Probably underreported in the United States

B. Scombrotoxin (scombroid poisoning; histamine poisoning): Ingestion of food containing high levels of histamine, including spoiled fishery products such as tuna and mahi mahi; swiss cheese; any food containing appropriate amino acids (histidine) and subject to bacterial metabolism
 1. Illness may include sensation of "tingling" in the mouth, upper body rash, and hypotension, then nausea, vomiting, and diarrhea that can be severe
 2. Common form of fish poisoning in United States but probably underreported
 3. Cooking, freezing, or canning has no effect on toxic reactions

C. Tetrodotoxin (pufferfish poisoning: Severe violent poisoning following ingestion of contaminated puffer fish, especially in Japan with few cases reported in the United States; a variety of CNS signs with paralysis, cardiac arrhythmia, and death within 4 to 8 hours

D. Shellfish poisoning (shellfish-associated toxins): Caused by dinoflagellates (planktonic algae), elaborating as many as 20 toxins, ingested by shellfish
 1. Types of shellfish poisoning
 a. Diarrheal shellfish poisoning (DSP): Nausea through diarrhea with chills, fever, and headache
 b. Neurotoxic (NSP): Tingling and numbness of lips, tongue, etc., muscle pain, dizziness, diarrhea, vomiting
 c. Paralytic (PSP): Numbness and tingling, other signs, paralysis
 d. Amnesic (ASP): Vomiting, abdominal cramping, diarrhea, seizures, coma
 2. Onset: Minutes to 2 to 3 hours, depending on toxin

GENERAL PRECAUTIONS FOOD SAFETY

Food safety begins at farms with appropriate sanitation procedures and extends to processing procedures and facilities, distribution processes, and the home (farm-to-fork).

I. Drink only potable water. Avoid swallowing recreational water
II. Wash and process foods in potable water
III. Wash hands and wash or disinfect food preparation areas often and thoroughly. Hands should be washed for 20 seconds with soap and warm water before and after handling raw food
IV. Refrigerate promptly (1 to 2 hours)
V. Avoid leaking meat and other food packages
VI. Cook or freeze fresh meat, poultry, ground meats within 2 days
VII. Avoid cross-contamination; keep raw meats and poultry away from other foods
VIII. Cutting boards and food preparation surfaces can be disinfected with solution of 1 tablespoon of unscented liquid bleach in 1 gallon of water
IX. Marinate meat and poultry in covered dish in refrigerator
X. Thaw frozen meat in refrigerator or in leak-proof plastic bag by submerging in cold tap water changed every 30 minutes
XI. Thoroughly cook all raw meats and poultry before eating
 A. Ground beef, veal, or lamb: Cook to 160° F
 B. Beef, veal, lamb steaks, roasts, and chops: Cook to 145° F
 C. Pork: Cooked to 160° F
 D. Poultry: Minimum internal temperature 165° F
XII. Other: Consult USDA Safe Food Handling Fact Sheet at: www.fsis.usda.gov/fact_sheets/basics_for_handling_food_safely/index.asp.

Supplemental Reading

Books

Corlett DA Jr. *HACCP User's Manual*. Gaithersburg, Maryland, 1998, Aspen Publishers.

Hubbert WT, Hagstad HV, Spangler E, Hinton MH, Hughes KL. *Food Safety and Quality Assurance Foods of Animal Origin.* Ames, Iowa, 1997, Iowa State University Press.

Hui VH, Pierson MD, Gorham RJ, eds. *Foodborne Disease Handbook,* 2nd ed., vol 1. *Bacterial Pathogens.* New York, 2001, Marcel Dekker.

Hui YH, Pierson MD, Gorham RJ, eds. *Foodborne Disease Handbook,* 2nd ed., vol 2. *Viruses, Parasites, Pathogens and HACCP.* New York, 2001, Marcel Dekker.

Websites

Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Parasitic Diseases. DPDx. Parasites and Parasitic Diseases. Parasites of the Intestinal Tract. http://www.dpd.cdc.gov/dpdx

Centers for Disease Control and Prevention, Division of Bacterial and Mycotic Diseases. Foodborne Illness. http://www.cdc.gov/ncidod/diseases/food/

Centers for Disease Control and Prevention, Food Safety Office, Foodborne diseases, pathogens and toxins. http://www.cdc.gov/foodsafety

United States Food and Drug Administration. Center for Food Safety and Applied Nutrition. Bad Bug Book. Foodborne Pathogenic Microorganisms and Natural Toxins Handbook. http://www.cfsan.fda.gov/~mow/intro.html

United States Food and Drug Administration. Center for Food Safety and Applied Nutrition. Consumer Advice and Publications on Food Safety, Nutrition, and Cosmetics. http://www.foodsafety.gov/~lrd/advise.html

United States Department of Agriculture. Food Safety Information Center. http://foodsafety.nal.usda.gov

World Health Organization. Zoonoses and veterinary public health. http://www.who.int/zoonoses/en/

World Health Organization. Food Safety. http://www.who.int/topics/food_safety/en/

7 CHAPTER

Necropsy Techniques

Jon S. Patterson

EXTERNAL EXAMINATION

I. Before beginning the necropsy:
 A. Obtain a body weight on the animal
 B. Record any identification numbers (e.g., ear tags, tattoos)
II. Note any external abnormalities
 A. Cutaneous abrasions, lacerations, hemorrhages, masses
 B. Areas of acanthosis, hyperkeratosis, excessive pigmentation (melanosis) or hypopigmentation
 C. Areas of inflammation or crusting in unpigmented areas of skin (e.g., photosensitive dermatitis)
 D. Interdigital inflammation, ulcers, pustules, blisters
 E. External parasites (fleas, mites, ticks, lice)
 F. Nasal, ocular, vulvar, penile discharges
 G. Diarrhea
 H. Exudate in external ear canals
 I. Dental tartar, gingivitis, oral ulcers
 J. Subcutaneous edema
 1. Dependent edema (ventral neck, limbs)
 2. Pitting edema
III. Note the body condition of the animal
 A. Thin, emaciated, obese
 B. Body-condition scoring system may be used
 C. Dehydration: Measured postmortem by degree of withdrawal of eyes into orbits
 D. Mucous membranes
 1. Pale: Anemia
 2. Bluish or purplish: Cyanosis
 3. Dark red: Injected, "toxic"

EXAMINATION OF THE MUSCULOSKELETAL SYSTEM

I. Gross examination of skeletal muscle
 A. Volume
 1. Atrophy or hypertrophy
 2. Assess symmetry, right vs. left side
 B. Color
 1. Pale (lighter brown than normal, tan, or white)
 a. Degeneration or necrosis
 b. May indicate streaks of adipose tissue
 2. Darker red brown than normal
 a. Myoglobin staining (from extensive necrosis)
 b. Hemorrhage or inflammation
 3. Focal discolorations associated with injected medications
 C. Texture
 1. Gelatinous: Edema, degeneration, necrosis
 2. Chalky, firm, gritty areas
 a. Dystrophic calcification
 b. Nutritional myopathy (vitamin E or selenium deficiency)
 3. Soft, friable: Inflammation, necrosis
 D. Postmortem changes
 1. Rigor mortis: Stiffening of the muscles
 a. Occurs 2 to 4 hours after death and lasts 1 to 2 days
 b. Time of onset depends on muscle activity, nutritional status, and body and environmental temperature at time of death
 c. Rigor begins in myocardium, then progresses to skeletal muscles of the head and neck and then to extremities
 2. Muscle relaxation occurs after rigor as muscle protein begins to degrade
II. Gross examination of bones
 A. Routine necropsy includes examination of at least one long bone and two to three joints. Cut a long bone (e.g., femur) longitudinally
 1. Assess diaphyseal bone marrow fat stores
 a. Normally opaque white to tan in adults
 b. Serous atrophy of fat: Gelatinous
 2. Assess hematopoietic activity. Red areas indicate active hematopoiesis
 3. Assess thickness of cortical bone, amount and distribution of cancellous or trabecular bone
 4. Assess thickness and uniformity of metaphyseal growth plates in growing animals
 B. Joints examined typically include the following:
 1. Coxofemoral
 2. Tibiotarsal-tarsometatarsal
 3. Radiocarpal-carpometacarpal
 C. Assess articular cartilaginous surfaces
 1. Erosions, ulcers
 2. Cracks or fissures
 3. Periarticular bony proliferation (osteophytes)
 D. Assess quality and volume of joint fluid
 1. Normal: Viscous, stringy, clear
 2. Fibrin: Suggests inflammation, possibly septicemia
 3. Watery or cloudy: Suggests inflammation or infection
 E. Fractures. Often associated with subcutaneous or intramuscular hemorrhage, edema, or tissue necrosis

F. Luxations or subluxations: May be associated with subcutaneous or intramuscular hemorrhage, edema, or tissue damage
G. Assess degree of ossification or calcification of long bones or ribs by digital pressure
1. Normal rib should snap under digital pressure
2. Rib with osteoid or calcium deficiency (i.e., metabolic bone disease) will bend extensively before it breaks (rubbery consistency, if severe)
H. Serous atrophy of diaphyseal bone marrow fat
1. Best appreciated in long bones, such as femur
2. Other sites of serous fat atrophy include epicardium, pericardium, perirenal fat, mesentery, and omentum

III. Some common myopathies
A. Clostridial myositis ("blackleg"): *Clostridium chauvoei*. Beef cattle, dairy cattle
B. *Arcanobacterium pyogenes* abscesses: Cattle
C. Sarcocystosis (protozoal myopathy)
1. Cattle
2. Usually an incidental finding, detectible only histologically
3. If severe, there may be grossly appreciable tan foci in muscle
D. Nutritional myopathy: Vitamin E or selenium deficiency → myodegeneration, necrosis
E. Malignant hyperthermia
1. "Porcine stress syndrome"
2. Genetic predisposition in certain strains of swine

IV. Some common bone diseases
A. Rickets
1. Defective endochondral ossification in growing animals
2. Bone deformities and pathologic fractures
3. Thickened growth plates that fail to mineralize
4. Vitamin D, calcium, or phosphorus deficiency
B. Osteomalacia
1. Softening or weakening of bone in adult animals
2. Vitamin D or phosphorus deficiency, chronic renal disease, or chronic fluorosis
C. Fibrous osteodystrophy: Resorption of bone and replacement by fibrous tissue associated with primary, secondary, or pseudohyperparathyroidism
D. Osteosarcoma
1. Arise most commonly at metaphyses of distal radius, distal tibia, and proximal humerus
2. Most common in mature large- and giant-breed dogs
E. Degenerative joint disease
1. Articular erosions, ulcers, osteophytes
2. Age-related or secondary to other primary bone disease (e.g., cervical vertebral malformation-malarticulation)
F. Intervertebral disc disease
1. "Chondroid degeneration" of discs in chondrodystrophic breeds of dogs
2. "Fibrous degeneration" of discs in nonchondrodystrophic breeds

EXAMINATION OF THE RESPIRATORY SYSTEM

I. Gross examination of the thoracic cavity
A. Puncture diaphragm from abdominal cavity to assess negative pressure in thorax
1. Perceivable inrush of air to thorax and billowing of diaphragm toward abdomen if animal has been dead less than a few hours
2. Lack of this movement may indicate pneumothorax, pleural effusion, or noncollapsible lungs owing to pulmonary edema, pneumonia, fibrosis, or emphysema
B. Rib cage
1. Fibrinous adhesions between visceral and parietal pleura indicate acute pleuritis
2. Fibrous adhesions between visceral and parietal pleura indicate chronic pleuritis or healed lesions from previous pleuritis
3. Check for rib fractures
C. Tongue, pharynx, larynx, trachea, bronchi, lungs, and heart are removed as one ("pluck"), and examined outside of the animal
D. Estimate volume of fluid, if any, in thoracic cavity. A small volume of serous fluid is normal

II. Nasal cavities
A. Turbinate atrophy (e.g., atrophic rhinitis of swine [*Pasteurella multocida* type D])
B. Catarrhal rhinitis
1. Increased volume of mucous exudates
2. Bacterial or viral causes or implies relatively mild inflammation
C. Suppurative rhinitis: Bacterial causes are most likely
D. Granulomatous rhinitis
1. Thick, less fluid exudate or no grossly visible exudates
2. Chronic
3. May be thickening of mucosal lining or polypoid nodules
4. Fungi, higher bacteria, foreign bodies

III. Sinuses
A. Sinusitis often occurs in combination with rhinitis. May be a sequela to septic wound (e.g., dehorning in cattle, tooth infection in horses and dogs)
B. Chronic sinusitis may extend into adjacent bone (osteomyelitis) or cribriform plate to cranial cavity (leading to meningitis or encephalitis)
C. Common causes of rhinitis and sinusitis
1. Horses
a. Equine herpesvirus (EHV-1 and EHV-4)
b. Equine influenza virus
c. Equine adenovirus (especially severe in Arabian foals with combined immunodeficiency)
2. Cattle
a. Infectious bovine rhinotracheitis virus (BHV-1). Pseudomembranous or fibrinonecrotic
b. Malignant catarrhal fever (bovine herpesvirus-2 outside of Africa). Ocular and nervous system inflammation as well

3. Swine
 a. Atrophic rhinitis (*Pasturella multocida* type D)
 b. Inclusion body rhinitis (cytomegalovirus, a herpesvirus)
4. Dogs
 a. Canine distemper virus, canine adenovirus types 1 and 2, parainfluenzavirus
 b. *Bordetella bronchiseptica*, *P. multocida*, *Escherichia coli*
 c. *Aspergillus* spp., *Cryptococcus neoformans*, *Rhinosporidium seeberi*
5. Cats
 a. Feline viral rhinotracheitis (FVR; herpesvirus-1), feline calicivirus
 b. *Chlamydia felis*. Also conjunctivitis
 c. *Mycoplasma felis*. Also conjunctivitis
 d. *Cryptococcus neoformans*

IV. Pharynx, larynx, and trachea
 A. Anomalies
 1. Brachycephalic airway syndrome (dogs)
 a. Stenotic nares, elongated soft palate
 b. Secondary nasal and laryngeal edema
 2. Dorsal displacement of soft palate in horses. Hypoplastic epiglottis prone to entrapment
 3. Tracheal or tracheobronchial collapse
 a. Toy and miniature breed dogs
 b. Dorsoventral flattening of trachea, with wide dorsal membrane
 B. Laryngeal hemiplegia of horses
 1. Idiopathic, traumatic, or inflammatory injury to left recurrent laryngeal nerve
 2. Muscle atrophy of dorsal and lateral cricoarytenoideus muscles
 C. Inflammation
 1. Redness
 2. Fibrinous or suppurative exudate
 3. May obstruct airflow or lead to secondary bronchopneumonia
 4. Guttural pouch inflammation in horses (Figure 7-1)
 a. *Aspergillus* spp.
 b. Usually unilateral
 c. Erosion into internal carotid artery may lead to epistaxis
 d. Empyema of guttural pouches may be a sequela to suppurative rhinitis, most commonly caused by *Streptococcus equi*
 5. Necrotic laryngitis ("calf diphtheria")
 a. Pseudomembranous
 b. *Fusobacterium necrophorum* infection
 6. Canine infectious tracheobronchitis ("kennel cough"). *Bordetella bronchiseptica*, canine adenovirus 2 or canine parainfluenzavirus
 D. White, foamy fluid in upper respiratory tract suggests pulmonary edema
 E. Free fibrin or suppurative exudate in the absence of redness or a pseudomembrane suggests inflammation from lower respiratory tract

V. Tracheobronchial lymph nodes
 A. Red and wet suggest acute inflammation
 B. White or tan foci suggest necrosis, inflammation, or lymphoid hyperplasia



Figure 7-1 Guttural pouch empyema, guttural pouch, horse. **A,** Note the swollen right neck (outlined) in this horse with guttural pouch empyema. **B,** The guttural pouch is filled with masses of inspissated purulent exudate *(arrow)*. (**A,** Courtesy College of Veterinary Medicine, University of Illinois. **B,** Courtesy Dr. M.D. McGavin, College of Veterinary Medicine, University of Tennessee.)

VI. Lungs
 A. Texture or consistency is the most important feature to evaluate
 1. Spongy: Normal. Implies lung is adequately aerated
 2. Rubbery
 a. Atelectasis (i.e., not adequately inflated, aerated, or expanded). Determine whether a newborn animal found dead took a breath by immersing a piece of lung tissue in water or fixative
 (1) If it floats, the animal took a breath
 (2) If it sinks, the animal was stillborn
 b. Fetal lungs should be atelectatic
 c. Congested lungs may be slightly rubbery. Diffusely red, ooze blood on cut section
 d. Edematous lungs may be rubbery. Ooze watery or foamy fluid on cut section
 3. Firm or consolidated
 a. Implies compromise of alveolar spaces
 (1) Exudate within alveolar spaces
 or
 (2) Narrowing of alveolar spaces because of thickening of alveolar walls (often by inflammation)

b. Consolidation with retention of the shape of the lungs suggests inflammation (i.e., pneumonia)

4. Patterns of pneumonia
 a. Diffuse
 (1) Implies infectious agent entered lungs via bloodstream
 (2) Typical pattern for viral pneumonias
 (3) Inflammation is typically in the alveolar walls, which means it is an *interstitial pneumonia*
 b. Locally extensive
 (1) Cranioventral distribution implies infectious agent entered lungs via inhalation
 (2) Typical pattern for bacterial pneumonias
 (3) Inflammatory exudate is typically in bronchi, bronchioles, and alveoli, which means it is a *bronchopneumonia*
 (4) *Aspiration pneumonia* is a bronchopneumonia. Exudate tends to be more necrotizing than suppurative
 c. Focal
 (1) Abscess or granuloma
 (2) Blood-borne or inhaled agent
 d. Multifocal: Most likely, blood-borne infection (i.e., *embolic pneumonia*)

B. Color
1. Red
 a. Diffuse congestion (active or passive hyperemia)
 b. Acute inflammation
2. Gray-red, plum-colored, dark red, or purple
 a. Subacute to chronic inflammation
 b. Atelectasis
3. White or tan areas or foci
 a. Inflammation (abscesses, granulomas)
 b. Fibrosis
 c. Necrosis

C. Common causes of pneumonia
1. Horses
 a. *Rhodococcus equi*: Bronchopneumonia in foals
 b. *Streptococcus equi*: Bronchopneumonia
 c. *Streptococcus zooepidemicus*: Bronchopneumonia or pleuritis
 d. Adenovirus (Arabian foals with combined immunodeficiency disease [CID]). Bronchopneumonia
 e. *Pneumocystis carinii* (Arabian foals with CID). Interstitial pneumonia
2. Cattle
 a. *Mannheimia haemolytica*: Acute bronchopneumonia and pleuritis
 b. *Pasteurella multocida*: Secondary opportunist; bronchopneumonia
 c. *Mycoplasma bovis*: Subacute to chronic bronchopneumonia
 d. *Histophilus somni*: Bronchopneumonia with or without pleuritis
 e. *Arcanobacterium pyogenes*: Secondary opportunist; abscesses
 f. Bovine respiratory syncytial virus
 g. Infection with IBR virus, parainfluenzavirus, or bovine viral diarrhea (BVD) virus may predispose to secondary bacterial pneumonia
3. Sheep and goats
 a. *Mannheimia haemolytica*
 b. Lentivirus (lymphoid interstitial pneumonia of sheep; caprine arthritis-encephalitis virus of goats)
 c. Lungworms (*Dictyocaulus filaria*, *Muellerius capillaris*, *Protostrongylus rufescens*)
4. Swine
 a. *Pasteurella multocida*: Bronchopneumonia
 b. *Actinobacillus pleuropneumoniae*
 (1) Acute fibrinohemorrhagic bronchopneumonia and pleuritis
 (2) Preferentially affects dorsocaudal areas of the lungs
 c. *Mycoplasma hyopneumoniae*: Subacute to chronic bronchopneumonia
 d. *Streptococcus suis* type II: Bronchopneumonia or pleuritis
 e. *Myoplasma hyorhinis*: Pleuritis as part of polyserositis syndrome
 f. *Hemophilus parasuis*: Bronchopneumonia or pleuritis or polyserositis (Glasser disease)
 g. Porcine respiratory and reproductive syndrome (PRRS) virus
 h. Porcine circovirus (postweaning multisystemic wasting syndrome)
 i. Swine influenzavirus
5. Dogs
 a. Canine distemper virus
 b. Canine adenovirus type 2
 c. Canine herpesvirus (neonates)
 d. Bacterial pneumonias generally secondary to immunocompromise. *Bordetella bronchiseptica, Pasteurella multocida, E. coli, Klebsiella pneumoniae*
 e. Fungal pneumonias
 (1) *Blastomyces dermatitidis, Histoplasma capsulatum, Coccidioides immitis, Cryptococcus neoformans*
 (2) *Aspergillus fumigatus* (immunocompromised animals)
 f. *Toxoplasma gondii*
6. Cats
 a. Feline rhinotracheitis virus and calicivirus may cause pneumonia but not a significant problem unless there is secondary bacterial infection
 b. *Cryptococcus neoformans*

VII. Neoplasms of the respiratory tract
A. Primary neoplasms are uncommon
1. Bronchogenic (bronchial origin), bronchiolar, alveolar, and bronchial gland carcinoma
2. Nasal adenocarcinoma

B. Lungs are a common site of metastasis of carcinomas and sarcomas

VIII. Pleural effusions
A. Hydrothorax
1. "Edema" of the thoracic cavity

2. Common causes include right-sided heart failure and hypoproteinemia
B. Hemothorax: Usually traumatic in origin
C. Chylothorax: Most commonly due to ruptured lymphatic duct (e.g., thoracic duct)
D. Pyothorax: Common causes:
1. Ruptured lung abscess
2. Extension of pneumonia or pleuritis caused by pyogenic bacterium
3. Puncture wound of thoracic wall
4. Traumatic reticulopericarditis sequelae in cattle

EXAMINATION OF THE CARDIOVASCULAR SYSTEM

I. Pericardium
A. A small amount of serosanguineous fluid in pericardial sac may be normal or a postmortem artifact
B. Hydropericardium
1. Excessive volume of clear to slightly yellow, watery to serous fluid
2. In diseases associated with generalized edema (e.g., congestive heart failure, hypoproteinemia)
3. Often accompanies ascites, hydrothorax
C. Pericardial sac containing clotted or unclotted blood: Hemopericardium. Rapid accumulation of blood leading to signs of acute heart failure: Cardiac tamponade
D. Fibrinous or fibrinosuppurative exudate
1. Bacterial pericarditis
2. Component of acute polyserositis
3. Associated with traumatic reticulopericarditis in cattle (i.e., hardware disease)
4. Inflammatory exudate may accompany adhesions to epicardium, visceral pleura, parietal pleura
E. Urate deposits on pericardial sac
1. Visceral gout in birds, reptiles
2. White, chalky deposits
II. External evaluation of the heart
A. Heart should taper toward apex and appear rounded at base
B. "Double apex" implies dilated right or left ventricular chamber
C. Excessively rounded at base implies dilated right or left atrial chamber
D. Petechiae or ecchymoses on epicardium
1. May indicate septicemia or endotoxemia
2. May be related to "agonal death," especially in large animals
3. Similar hemorrhages may be seen on endocardium
E. Hemangiosarcoma of dogs. Commonly found in right atrium or auricle
III. Myocardium
A. Ratio of the thickness of the free wall of the left ventricle to the thickness of the free wall of the right ventricle is normally 2:1 to 3:1
B. Tan streaks in myocardium suggest myodegeneration, myonecrosis, myocarditis, or fatty infiltration. Areas of pallor may be due to postmortem autolysis, too
C. Hypertrophic cardiomyopathy (HCM) of cats. Thickening of left ventricular free wall and interventricular septum primarily
D. Dilative cardiomyopathy of cats, congestive heart failure of any species
1. Rounded heart externally
2. Often biventricular dilation
E. Postmortem blood clotting
1. "Currant jelly" clots: Dark red, gelatinous
2. "Chicken fat" clots: Separation of serum from cellular components
F. Ossa cordis: Two normal, triangular-shaped bones palpable in the interventricular septum near the base of the heart in cattle
IV. Endocardium
A. Endocardium covering myocardium is thin and transparent in small animals but may be white diffusely or in patchy areas because of greater thickness in large animals
B. Atrioventricular valves (right: Tricuspid, left: Mitral). Normally smooth, thin, semitransparent (small animals) to white
C. Pulmonic and aortic valves
1. Normally smooth, thin, white
2. Small (1-2 mm) firm, palpable nodules in free edges of the cusps of the aortic valve in large animals
V. Great vessels
A. Great vessels entering or exiting the heart are commonly examined (i.e., jugular veins, venae cavae, pulmonary artery, pulmonary veins, aorta)
B. Thrombi
1. Antemortem thrombi are attached to vascular endothelium. "Laminated" appearance, with layers of fibrin and blood, may be appreciated
2. Postmortem blood clots are not attached and are easily removed from the blood vessel. Usually homogeneous, gelatinous
C. Atherosclerosis
1. Primary vascular disease is uncommon in animals
2. Atherosclerosis may be seen as a sequela to hypothyroidism or diabetes mellitus
3. Thick-walled, pale yellow, tortuous arteries
VI. Some common cardiac congenital anomalies
A. Dogs
1. Patent ductus arteriosus: Several breeds (mostly small dogs)
2. Pulmonic stenosis: Inherited in beagle, English bulldog, Chihuahua
3. Subaortic stenosis: Inherited in Newfoundland, boxer, German shepherd
4. Persistent right aortic arch: Predisposition in German shepherd, Irish setter, Great Dane
B. Cats: Endocardial fibroelastosis. Burmese cats
C. Cattle
1. Ventricular septal defect: Usually toward the heart base
2. Valvular hematomas (hematocysts)
a. Atrioventricular valves of young animals
b. Seem to regress spontaneously
c. Not associated with functional abnormalities

D. Pigs: Subaortic stenosis

VII. Inflammatory diseases of the heart
A. Bacterial endocarditis
1. Usually valvular
2. Dull, friable, yellow to gray masses of fibrin, exudate, necrotic debris
3. Fibrous base to these "vegetative" growths implies chronicity
4. Affected animal often has pre-existing extracardiac infection (e.g., dental or oral, liver abscess)
5. Isolates include *Arcanobacterium pyogenes* in cattle, *Streptococcus* spp., and *Erysipelothrix rhusiopathiae* in swine, *Streptococcus* spp., and *E. coli* in dogs and cats
B. Myocarditis
1. Hematogenous spread of infection
2. Usually multifocal white to tan foci or streaks in myocardium
3. Some bacterial causes
a. *Clostridium chauvoei* in cattle (blackleg): Dark red foci of hemorrhage and necrosis
b. *Clostridium piliformis* (Tyzzer disease) in foals and laboratory animal species
4. Some viral causes
a. Canine parvovirus
b. Porcine encephalomyocarditis virus
c. Foot-and-mouth disease virus
5. Some protozoal causes
a. *Toxoplasma gondii*
b. *Sarcocystis* spp.
c. Often an incidental finding, without accompanying inflammation, in cattle

VIII. Conditions associated with degeneration or necrosis
A. Valvular endocardiosis of aged dogs
1. Multinodular thickening of atrioventricular valves
2. "Verrucous" or wartlike nodules, associated with mitral regurgitation murmurs
B. Nutritional myopathy: Most commonly associated with vitamin E or selenium deficiency
C. Toxic cardiomyopathy (e.g., ionophores, vitamin D, certain mycotoxins)

IX. Cardiovascular neoplasia
A. Hemangiosarcoma in dogs
1. Right atrium or auricle
2. Also commonly found in spleen, liver
3. Dark red, rather soft, with blood-filled channels
B. Lymphosarcoma in cattle
1. Right side of the heart most frequently
2. Firm, tan, homogeneous masses
3. Other common sites include abomasum and uterus

EXAMINATION OF THE GASTROINTESTINAL (GI) TRACT

I. Oral cavity
A. Developmental anomalies
1. Palatoschisis (cleft palate)
2. Cheiloschisis (cleft lip)
B. Erosions, ulcers, vesicles, papules on tongue, gingiva, buccal mucosa, or lips
1. May indicate viral infection (e.g., foot-and-mouth disease of ruminants, vesicular stomatitis of calves, vesicular exanthema of swine, bovine papular stomatitis), contagious ecthyma ("orf" or "sore mouth") of sheep and goats, bovine viral diarrhea (BVD) virus, feline calicivirus
2. May start as clear fluid-filled vesicles or blisters
3. For some diseases, there may be similar lesions on coronary bands of hooves, udder, or mucocutaneous junctions
4. Bacterial causes
a. *Fusobacterium necrophorum*
(1) "Calf diphtheria"
(2) Necrotizing or pseudomembranous stomatitis
b. May occur secondary to viral infection
5. Other causes
a. Chemical injury
b. Associated with systemic disease (e.g., uremia)
c. Autoimmune disease
d. Trauma
C. Hyperplastic lesions
1. Gingival hyperplasia
2. Epulis
a. Indistinguishable grossly from gingival hyperplasia
b. Several histopathologic variants, one of which can be invasive or destructive (acanthomatous epulis)
D. Neoplasia
1. Squamous cell carcinoma
a. Tongue is most common site in cats
b. Tonsil is most common site in dogs
2. Oral melanoma: Usually malignant in dogs. Cutaneous melanomas tend to be benign
3. Canine oral papillomatosis
a. Caused by papovavirus
b. Usually in young animals
4. Fibrosarcoma: Cats and dogs
E. "Wooden tongue" in cattle
1. *Actinobacillus lignieresii*
2. Thickening of tongue owing to granulomatous inflammation and fibrosis
F. "Thrush"
1. *Candida albicans* (yeast) infection of tongue and esophagus
2. Secondary to an underlying debility, especially in young

II. Esophagus
A. Megaesophagus
1. Congenital
a. Associated with persistent right fourth aortic arch (Figure 7-2)
b. Esophageal obstruction at base of heart and dilation cranial to this site
2. Acquired
a. Dilation of entire esophagus
b. Atrophy or degeneration of the muscularis
c. Idiopathic, or secondary to the following:
(1) Myasthenia gravis



Figure 7-2 Megaesophagus from a persistent right aortic arch, esophagus, dog. Dilation of the esophagus cranial to the heart is the result of failure of the right fourth aortic arch to regress during embryonic life (vascular ring abnormality). (Courtesy Dr. C.S. Patton, College of Veterinary Medicine, University of Tennessee.)

(2) Polymyositis
(3) Hypothyroidism

B. Esophageal parasites
1. *Gongylonema* spp.
a. Ruminants, pigs, horses
b. Thin, red, serpentine nematodes beneath mucosal surface
2. *Spirocerca lupi* in dogs. Nematode associated with granulomas or neoplasms (fibrosarcoma, osteosarcoma)

C. Esophageal erosions or ulcers
1. Reflux of gastric acid → esophagitis
2. Injury associated with stomach tubes
3. Viral infection (e.g., BVD virus)
4. Ulcers tend to be linear

D. Idiopathic hypertrophy of the muscularis of the caudal esophagus in horses
1. Usually of no clinical significance
2. Muscle tends to be lighter brown than normal

E. "Choke"
1. Caused by lodging of large ingested bodies (e.g., potatoes, apples, bones) in the esophagus. Common sites:
a. Dorsal to larynx
b. At thoracic inlet
c. At base of heart
d. At diaphragmatic hiatus
2. Pressure necrosis → inflammation → healing or scarring → stricture
3. May be associated with poor teeth and incomplete mastication in older horses

III. Forestomachs (rumen, reticulum, omasum) of ruminants

A. Ruminal tympany (bloat)
1. Overdistention of rumen (and reticulum) by gas produced during fermentation
2. Primary tympany
a. "Legume bloat," "dietary bloat," or "frothy bloat"
b. Associated with change in diet or certain legumes (e.g., alfalfa) or grain concentrates
3. Secondary tympany
a. Physical or functional esophageal obstruction → failure to eructate
b. For example, vagal indigestion, esophageal foreign body, lymphosarcoma
4. Antemortem vs. postmortem bloat. Sharp line of demarcation between the blanched caudal esophagus and the congested cranial esophagus at the thoracic inlet implies antemortem bloat ("bloat line")

B. Rumenitis due to lactic acidosis ("grain overload")
1. Abundant grain in rumen
2. Brown, friable, easily detached ruminal papillae. This may also be a postmortem artifact if the animal has been dead for even a few hours at high environmental temperature
3. Secondary bacterial infection with *A. pyogenes* or *Fusobacterium necrophorum* → liver abscesses

C. Mycotic rumenitis
1. Secondary to lactic acidosis, ruminal mucosal mechanical injury, or antibiotic administration
2. Discrete, round ulcers associated with vasculitis and thrombosis (infarction) (Figure 7-3)
3. *Mucor*, *Rhizopus*, *Absidia*, *Mortierella*, *Aspergillus* spp.

D. Effects of diet on ruminal papillae
1. High roughage diet → increased length of papillae
2. Low roughage (less than 10%) diet → parakeratosis and clumped papillae

E. Traumatic reticulopericarditis ("hardware disease")
1. Foreign object is usually sharp and approximately 7 to 12 cm long (nail, wire)
2. Perforates reticulum and possibly diaphragm and pericardium
3. Reticulitis: Red zone around foreign body
4. Fibrinous exudate in pericardial sac and coating epicardium ("bread and butter heart")
5. Fibrous thickening of wall of reticulum and pericardium implies that reaction is chronic

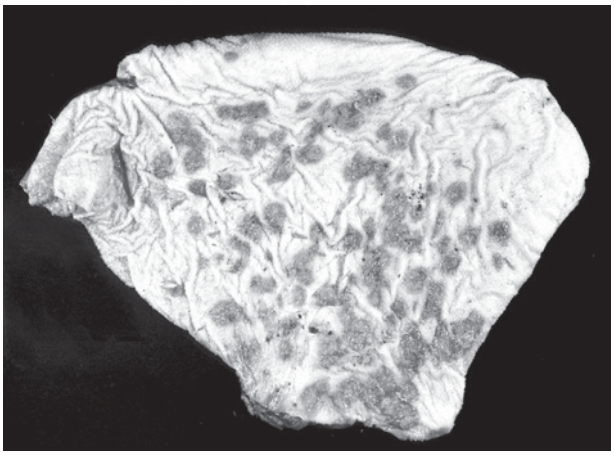


Figure 7-3 Mycotic rumenitis, rumen, calf. Note the numerous well-demarcated foci of necrosis and hemorrhage (infarcts) in the ruminal mucosa that can be caused by angioinvasive fungi such as *Aspergillus*, *Mucor*, *Rhizopus*, *Absidia*, and *Mortierella* spp. This type of mycotic infection is usually preceded by a chemical (lactic acid) rumenitis (overeating). (Courtesy Dr. H. Gelberg, College of Veterinary Medicine, Oregon State University).

IV. Stomach and abomasum
 A. Normal anatomy
 1. Nonglandular (stratified squamous lined) adoral portion of the mucosa in horses and rats. White to tan, smooth, firm
 2. Small, square nonglandular portion surrounding the esophageal cardia in swine
 3. Glandular mucosa diffusely in other species. Smooth, glistening, or velvety texture normally
 B. Gastric dilatation and volvulus
 1. Especially in large, deep-chested dogs
 2. Associated with overfeeding, postprandial exercise, and possibly an inherited predisposition to gastric rotation
 3. Rotation is generally clockwise on the ventrodorsal axis when abdomen is viewed from ventral aspect
 4. Dark red areas of passive hyperemia and infarction of gastric wall
 5. Accompanying splenic enlargement due to congestion
 C. Gastric dilatation in horses
 1. Grain overload or overeating
 2. Gaseous distention, which may lead to gastric rupture
 3. May be a terminal event in intestinal obstruction and displacement
 4. Determining whether a rupture is antemortem or postmortem
 a. Evidence of hemorrhage or inflammation (e.g., fibrin strands) at the edges of the perforation indicates antemortem rupture
 b. Distribution of gastric contents throughout abdomen is *not* a reliable indicator of antemortem or postmortem rupture (i.e., this may occur with antemortem or postmortem rupture)
 D. Gastritis or abomasitis
 1. Redness of gastric mucosa may be "physiologic hyperemia" associated with recent feed ingestion and is not necessarily an indication of inflammation
 2. Emphysematous gastritis or abomasitis
 a. Gas contributes to thickening of gastric wall
 b. Associated with gas-producing bacteria
 i. For example, *Clostridium perfringens*. Also, mural hemorrhage and edema
 ii. For example, *Clostridium septicum* ("braxy"). Hemorrhagic abomasitis in sheep and cattle
 3. Erosions and ulcers in general
 a. Erosion: Necrosis does not extend beyond the basement of the mucosal epithelium. Depression in mucosa is not appreciable
 b. Ulcer: Necrosis extends deeper than the basement membrane. Shallow to deep depression and loss of normal glistening appearance are seen
 c. Conditions for ulcer development represent an imbalance between hydrochloric acid secretion and mucus production. Associated with injury to mucosal epithelium, excess acidity, regional ischemia, decreased prostaglandin production (steroids or nonsteroidal antiinflammatory drugs [NSAIDs])
 4. Abomasal ulcers in ruminants
 a. Calves
 i. Dietary change to roughage
 ii. Stress
 b. Adult cattle
 i. Lactic acidosis
 ii. Displaced abomasum
 iii. BVD virus infection
 iv. Impaction, torsion
 v. Lymphosarcoma
 5. Gastric ulcers in swine
 a. Finely ground grain
 b. Stratified squamous portion of mucosa
 6. Gastric ulcers in foals
 a. Stress
 b. NSAIDs
 7. Uremic gastritis
 a. In carnivores, secondary to chronic renal disease
 b. Mucosal redness grossly, calcification microscopically
 E. Gastric or abomasal parasites
 1. Equine bots
 a. Fly larvae of *Gasterophilus intestinalis* or *G. nasalis*, most commonly
 b. Along margo plicatus most commonly
 c. May be associated with ulcers
 2. *Draschia megastoma* in horses. Nodular "brood pouches" (granulomas) along margo plicatus
 3. *Haemonchus contortus* (nematode) of small ruminants
 a. "Barberpole worm"
 b. Associated with hemorrhage into abomasum → black, granular contents
 c. Anemia → pale mucous membranes
 4. *Ostertagia ostertagia* of cattle, *O. circumcincta* of small ruminants
 a. Thickened, "cobblestone" mucosa
 b. Associated with unthriftiness, hypoproteinemia
 F. Gastric or abomasal neoplasia
 1. Lymphosarcoma in cattle associated with bovine leukemia virus infection
 2. Squamous cell carcinoma of horses
 3. Glandular neoplasms (adenoma, adenocarcinoma) in dogs and cats
 4. Leiomyoma and leiomyosarcoma (rare) in any species
V. Intestine (small and large)
 A. General points regarding gross pathology
 1. Some degree of redness of the mucosa may be expected with physiologic hyperemia of digestion or absorption
 2. Normal serosal surfaces are tan to pink
 3. Normal mucosal and serosal surfaces are smooth and glistening
 4. Pseudomelanosis (black discoloration) or gray green discoloration is a common postmortem artifact when the animal has been dead for several hours to days

a. Caused by activity of intestinal microflora
b. Time interval between death and color changes is influenced by animal's body temperature, environmental temperature, and other factors

B. Intestinal obstruction
1. Foreign bodies
2. Enteroliths
a. Rare except in horses, with increased incidence in Arabians
b. Ammonium magnesium phosphate (struvite) around a nidus of foreign material
3. Sand: Often included in impacted material in horses
4. Roughage: High roughage diet in older horses with poor dentition
5. Common sites of intestinal obstruction in horses
a. Pelvic flexure
b. Right dorsal colon to transverse colon
c. Ileocecal junction
6. Intussusception
a. Telescoping of one segment of intestine into the immediately aboral segment, leading to obstruction
b. Associated with intestinal irritability and hypermotility
c. Associated with enteric parasites, foreign bodies, neoplasms
d. Ischemic necrosis of the intussusceptum (trapped segment). Dark red to black, friable, granular
7. Strangulation by mesenteric pedunculated lipoma in horses. Lipoma wraps around intestinal mesentery or a loop of small intestine, causing ischemic necrosis

C. Intestinal displacement
1. Herniation and entrapment through epiploic foramen
a. Horses
b. Ischemic necrosis of loop of small intestine
2. Herniation and entrapment through a tear in the mesentery
3. Herniation into an outpouching of parietal peritoneum (e.g., umbilical, diaphragmatic, inguinal, perianal)
4. Volvulus: Twisting of intestine on its mesenteric axis
5. Torsion: Rotation of intestine along its long axis
6. Both volvulus and torsion result in segmental ischemic necrosis
7. Renosplenic entrapment of the colon in horses
a. Left dorsal displacement of the left dorsal or left ventral colon between the spleen and the left side of the abdominal wall
b. Entrapment (and ischemic necrosis) over the renosplenic ligament between the left kidney and the spleen

D. Miscellaneous conditions
1. Idiopathic smooth muscle hypertrophy of the aboral ileum
a. Horses and pigs
b. Usually an incidental finding but may be associated with injury or inflammation
2. Hemomelasma ilei
a. Raised, pink to black, generally linear plaques on serosal surfaces of intestine, usually on ileum
b. Unique to horses
c. Fibrovascular tissue associated with strongyle larval migration along antimesenteric border
3. Aneurysm or thrombosis of cranial mesenteric artery
a. Migration of fourth-stage larvae of *Strongylus vulgaris* in horses
b. Roughening of vascular endothelium, with thrombosis
c. Weakening and outpouching of vascular wall
4. Lymphangiectasia of dogs
a. Congenital developmental defect
or
b. Acquired and secondary to chronic granulomatous inflammation or neoplasia that leads to lymphatic obstruction: Firm, gray white, often nodular thickenings along lymphatic chain and in wall of intestine

E. Infectious diseases that affect multiple species
1. Neonatal colibacillosis (enterotoxigenic *E. coli* infection)
a. Calves, small ruminants, pigs, foals
b. Dilated, flaccid, fluid-filled intestines
c. Chyle or milk is visible in mesenteric lacteals of nursing animals because this is a diarrhea of hypersecretion rather than malabsorption
2. Septicemic colibacillosis
a. Neonatal animals that have not received adequate passive immunity in colostrums
b. Intestinal lesions similar to neonatal colibacillosis, but also lesions of septicemia:
(1) Fibrinous arthritis
(2) Ophthalmitis (fibrin in anterior chambers of eyes)
(3) Polyserositis, meningitis
3. Post-weaning colibacillosis
a. Unique to pigs
b. Hemolytic *E. coli* strain
c. Dilated, fluid-filled intestines
4. Attaching and effacing colibacillosis (enteropathogenic *E. coli*)
a. Calves, pigs, lambs, dogs
b. Often in association with other intestinal pathogens
5. Salmonellosis
a. Enteroinvasive
b. Acute or chronic enteritis, colitis, or enterocolitis
c. Thickening of the mucosa, possibly with a pseudomembrane of fibrin and necrotic debris
d. Enlargement and increased prominence of Peyer patches, with necrosis of the overlying mucosal epithelium (ulcers)

e. Enlarged, edematous mesenteric lymph nodes with white foci of necrosis
f. Acute enteric salmonellosis
(1) Usually *S. typhimurium*
(2) Cattle, pigs, horses
(3) Fibrinous cholecystitis (fibrin and edema of gall bladder) is pathognomonic in calves
g. Chronic enteric salmonellosis
(1) "Button ulcers" in pigs
(2) Rectal stricture as a sequela to healed lesions in pig → obstipation, abdominal distention
h. Septicemic salmonellosis
(1) Usually *S. choleraesuis* in swine
(2) Paratyphoid nodules (white granulomatous foci) in liver
(3) Also may see meningitis (cloudy meninges), fibrinous arthritis, renal infarcts

6. Clostridial enteritis
a. *C. perfringens* classified as types A, B, C, D, or E, depending on production of one or more of four major toxins (alpha, beta, epsilon, iota)
b. Enterotoxemia
(1) Usually *C. perfringens* type D
(2) Well-fed young animals or change in diet to one high in carbohydrates
(3) Hemorrhages of small intestinal mucosa and serosa
(4) Thin-walled, gas-filled intestines
(5) *C. perfringens* type D also associated with "overeating disease"
(a). Multiorgan serosal hemorrhages
(b). Bilaterally symmetric encephalomalacia
c. Hemorrhagic enteritis
(1) *C. perfringens* type C
(2) Neonatal calves, lambs, pigs, foals
(3) Hemorrhage and necrosis of small intestine, including dark red contents

7. Tyzzer disease
a. *Clostridium piliformis*
b. Primarily targets liver, but lesions also seen in intestine and heart (especially in rodents and rabbits)
c. Among common domestic animal species, foal is most commonly affected
d. Mucosal necrosis and mural hyperemia and edema in ileum, cecum, or colon → ileitis, typhlitis, or colitis
e. White foci of hepatic and myocardial necrosis

8. Rotavirus
a. Each animal species has its specific rotavirus
b. Disease of neonates, especially calves and piglets
c. No gross lesions other than fluid-filled intestines
d. Often concomitant with other infectious causes of diarrhea

9. Coronavirus
a. Primarily young calves and pigs
b. Similar gross lesions as rotavirus, colibacillosis
c. Hemorrhagic form involving colon in cattle. Dark red, fibrinonecrotic pseudomembrane
d. Feline coronavirus usually a mild infection but may be severe and fatal
e. Canine coronavirus also usually a mild infection

10. Adenovirus
a. Young cattle, sheep, pigs, horses
b. Inapparent or mild respiratory disease as well as enteric disease
c. Arabian and Arab crossbreeds with CID: Severe respiratory disease
d. No obvious gross lesions in intestinal tract

11. Cryptosporidiosis
a. Cryptosporidium parvum
b. Protozoan most commonly associated with diarrheal disease in young animals, especially calves and piglets

12. Coccidiosis
a. Host- and tissue-specific protozoa: Eimeria and Isospora spp.
b. Gross lesions vary, depending on animal species
(1) Proliferative, "cobblestone" appearance of small intestinal mucosa in sheep and goats
(2) Hemorrhagic exudate calves, dogs, cats
(3) Fibrinonecrotic pseudomembrane in pigs

F. Infectious enteric diseases of swine
1. Transmissible gastroenteritis (TGE) virus
a. Piglets less than 10 days old
b. Severe diarrhea with undigested milk and foul odor
c. High morbidity and mortality
d. Severe thinning of small intestinal wall, with villous atrophy, which may be evident with a dissecting microscope at necropsy

2. Swine dysentery
a. Weanlings, 8 to 14 weeks old
b. Brachyspira hyodysenteriae, acting synergistically with anaerobic bacteria such as *Fusobacterium necrophorum* or *Bacteroides vulgatus*
c. Mucus and blood in colonic contents (mucohemorrhagic colitis)

3. Lawsonia intracellularis enteritis
a. Synonyms: Proliferative enteropathy, proliferative ileitis, intestinal adenomatosis
b. Severe intestinal mucosal necrosis and proliferation of crypt cells, most severe in the ileum → thickening of intestinal wall, necrotic debris with or without hemorrhage in lumen

G. Infectious enteric diseases of ruminants
1. Johne disease (paratuberculosis)
a. Severe diarrhea in cattle but not in sheep and goats
b. Severe emaciation and hypoproteinemia in all affected ruminants

c. Generally older than 18 months
d. *Mycobacterium avium* ssp. *paratuberculosis*
e. Thickened corrugated ileal mucosa caused by granulomatous inflammation in mucosa and submucosa

2. BVD virus
a. "Mucosal disease" in cattle
b. Usually younger than 2 years old
c. Noncytopathic BVD virus infection early in life (or in utero), then exposed to cytopathic strain later
d. Erosions and ulcers of tongue, gingiva, palate, esophagus, rumen, abomasums, coronary bands of hooves, as well as:
(1) Sharply demarcated areas of necrosis and ulceration over Peyer patches in intestinal tract

3. Winter dysentery
a. Dark brown to black feces with flecks of blood or mucus
b. Mostly in adult cattle, especially postparturient cows
c. Streaks of hemorrhage on colonic mucosa
d. Cause uncertain (coronavirus?)

H. Infectious enteric diseases of horses
1. Potomac horse fever
a. *Neorickettsia risticii* (rickettsial organism)
b. Hyperemia of cecal and colonic mucosa, with petechiae
c. Small segments of small intestine may also be involved

2. *Rhodococcus equi*
a. Ulcers and areas of pyogranulomatous inflammation (thickened, tan, corrugated) in cecum and colon, associated with lymphoid tissue
b. Enlarged, tan mesenteric and colonic lymph nodes, with caseous areas of granulomatous inflammation
c. Especially in young horses

3. Colitis X
a. Severe, acute-onset diarrhea without blood
b. Cause uncertain but often associated with disruption of normal microflora (e.g., antibiotic therapy) or "stress". Overgrowth by *Clostridium perfringens* type A
c. Marked thickening of cecal and colonic wall by hyperemia and edema, with multifocal hemorrhage

I. Infectious enteric diseases of carnivores
1. Canine parvovirus enteritis
a. Segmental reddening of small intestine
b. Serosal surfaces of small intestine may be granular, indicating peritonitis or serositis
c. Bloody intestinal contents

2. Feline panleukopenia virus. Parvovirus causing similar disease as canine parvovirus

3. Canine histoplasmosis
a. Along Ohio and Mississippi River valleys
b. *Histoplasma capsulatum*
c. Thickening of small intestine and colon by granulomatous inflammation
d. Enlargement of mesenteric and colonic lymph nodes

4. Feline infectious peritonitis (FIP)
a. Mutant form of feline enteric coronavirus
b. "Wet form" of disease. Fibrinous polyserositis, with thoracic or abdominal effusions (serous, yellow fluid)
c. "Dry" form. White to tan nodules (granulomas) centered around blood vessels on serosal surfaces of, and within viscera. Especially kidneys, intestines, liver, lungs

J. Some common enteric parasitic diseases
1. Ascarids (nematode roundworms) (Figure 7-4)
a. Associated with inflammation, obstruction, intussusception, especially in young animals
b. *Parascaris equorum* in horses
c. Ascaris suum in pigs
d. *Toxocara canis* in dogs

2. Hookworms
a. Associated with intestinal hemorrhage or blood loss
b. For example, Ancylostoma caninum in dogs

3. Whipworms
a. Cecum and colon
b. For example, *Trichuris vulpis* in dogs, *T. suis* in pigs

4. Oesophagostomum
a. Nodular worms of ruminants and pigs
b. Subserosal mineralized nodules
c. Generally no clinical significance

5. Cestodes (tapeworms)
a. May be frequently found but generally of no clinical significance
b. Species specific to small intestine or large intestine

6. Trematodes (flukes). Uncommon in intestine, more common in liver

K. Enteric neoplasia
1. Dogs
a. Adenomas or polyps of intestinal mucosa
b. Adenocarcinomas of stomach or intestine
c. Leiomyoma or leiomyosarcoma

2. Cats
a. Intestinal lymphosarcoma. This form is not commonly associated with feline leukemia virus
b. Intestinal mastocytosis

3. Cattle and horses. Intestinal lymphosarcoma

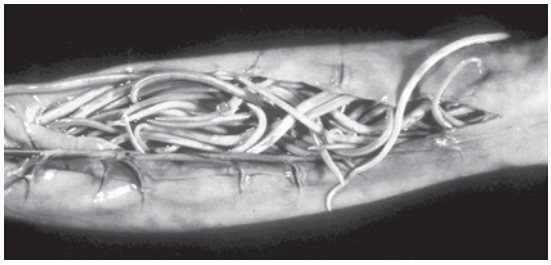


Figure 7-4 Ascarid impaction, jejunum, horse. Impaction was the result of a rapid "die off" of the ascarids as the result of administration of an anthelmintic. (Courtesy Dr. H. Gelberg, College of Veterinary Medicine, Oregon State University.)

EXAMINATION OF THE LIVER AND BILIARY SYSTEM

I. Postmortem changes in the liver
 A. Commonly seen because of high metabolic activity of the liver and movement of bacteria from GI tract into portal circulation and liver after death
 B. Pale brown or pink color on capsular surfaces owing to bacterial degradation
 C. Pseudomelanosis. Blue-black discoloration associated with degradation of blood pigments to hydrogen sulfide
 D. Bile imbibition. Green discoloration from leaching of bile pigments from gallbladder
 E. Emphysema. Gas production by bacteria, especially beneath capsular surfaces

II. Developmental defects of the liver
 A. Congenital portosystemic shunts
 1. Abnormal vascular channels in portal venous system, which cause blood flow to bypass the liver and spill into systemic circulation
 2. Intrahepatic or extrahepatic; usually involve only one vessel. May be difficult to identify at necropsy
 3. Most common in dogs and cats
 4. Grossly small liver
 B. Gallbladder anomalies
 1. Most common in cats
 2. Irregular shape of gall bladder or bile duct

III. Circulatory disturbances of the liver
 A. Passive congestion
 1. Associated with right-sided heart disease
 2. Increased prominence of central veins (so-called accentuated lobular pattern)
 3. If chronic, hypoxia causes swelling of centrilobular hepatocytes, so hepatic parenchyma surrounding central veins is lighter brown than normal
 a. So-called nutmeg liver
 b. Light color also due to fibrosis around central veins
 4. May be associated with portal hypertension and ascites
 B. Telangiectasis
 1. Foci of dilated sinusoids, where hepatocytes have atrophied or undergone necrosis
 2. Small, yet discrete, dark red areas
 3. Most common in cattle
 C. Infarction
 1. Uncommon in liver because of organ's dual blood supply (hepatic artery and portal vein)
 2. If infarcts occur, they are sharply demarcated, tan or dark red, and at margins of liver lobes
 3. Torsion of a liver lobe can cause infarction of the entire lobe

IV. Metabolic disturbances of the liver
 A. Hepatic lipidosis ("fatty liver syndrome")
 1. Cattle and cats, most commonly
 2. Enlarged liver, with rounded lobe margins
 3. Lighter brown than normal or tan to pale yellow
 4. Texture is friable or greasy
 5. Floats in water or fixative if concentration of lipid is high enough
 B. Steroid hepatopathy
 1. Excessive accumulation of glycogen in hepatocytes
 2. Occurs in dogs
 3. Associated with iatrogenic use of glucocorticosteroids or hyperadrenocorticism
 4. Enlarged liver with rounded lobe margins
 5. Lighter red-brown color than normal
 6. Friable texture but does not float in water or fixative
 C. Amyloidosis
 1. Liver is one of three organs in which AA amyloid deposition may be seen, most commonly as part of systemic amyloidosis (along with kidneys and spleen)
 2. Hepatomegaly, with waxy or friable texture and lighter brown color than normal
 D. Copper poisoning
 1. Ruminants (especially sheep)
 a. Dietary excess of copper
 b. Normal copper but insufficient molybdenum in soil
 c. Hepatotoxic plants → failure to excrete copper in bile
 2. Inherited copper metabolic disorders in certain breeds of dogs
 3. Sheep: Acute severe hemolysis and icterus from sudden release of copper from necrotic liver
 4. Dogs: Associated with chronic hepatitis

V. Patterns of hepatocellular degeneration and necrosis
 A. Random multifocal
 1. Typical of infectious causes
 2. If large enough to be visible grossly, foci are tan or white and discrete
 B. Zonal
 1. Centrilobular, midzonal, or periportal with respect to hepatic lobule. Enhanced lobular pattern grossly, but just which pattern it is usually must be determined histologically
 2. Liver may be enlarged and friable and mottled in color
 C. Massive
 1. Necrosis of an entire lobule, or contiguous lobules, or the entire liver
 2. Gross appearance depends on the stage of the lesions (acute vs. chronic)
 a. Liver may be enlarged, friable, with dark red areas of congestion early on
 b. May be shrunken with areas replaced by white fibrous tissue later on

VI. Nodular regeneration of the liver
 A. Nodular regeneration is common as a response to injury
 B. Capsular surface and cut surfaces may be irregular if significant regeneration has occurred, especially in combination with fibrosis in chronic conditions
 C. Cirrhosis: End-stage liver disease, associated with nodular regeneration, fibrosis, and biliary hyperplasia. Liver is smaller than normal and firmer than normal in texture (Figure 7-5)

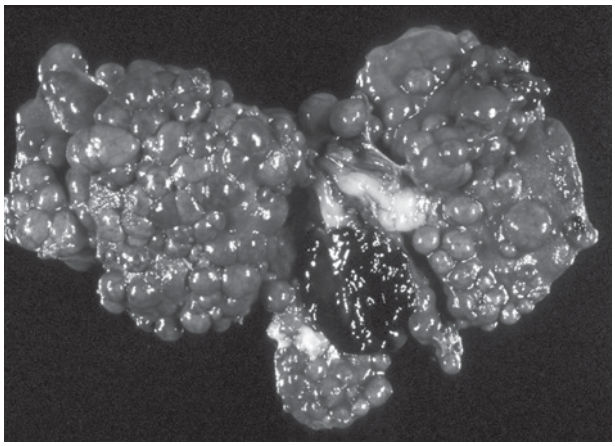


Figure 7-5 End-stage liver (cirrhosis), dog. End-stage liver from a dog that had received phenobarbital for many years. The liver is small, firm, and irregular with nodules of regenerative parenchyma separated by tracts of fibrous connective tissue. (Courtesy Dr. J.M. Cullen, College of Veterinary Medicine, North Carolina State University.)

VII. Inflammatory disease (hepatitis)
- A. Multifocal, random tan foci if inflammation is accompanied by necrosis
- B. Mottled appearance (red, tan, brown) if inflammation is diffuse
- C. Viral causes
 1. Herpesviruses in any species tend to cause multiple random, small (less than 1 mm), white foci of necrosis
 2. Infectious canine hepatitis: Predilection for vascular endothelium → petechiae and ecchymoses in many viscera as well as multifocal hepatic necrosis
- D. Bacterial causes
 1. Hepatic abscesses in feedlot cattle. *Fusobacterium necrophorum*
 2. Tyzzer disease
 a. *Clostridium piliformis*
 b. Foals and laboratory animals, most commonly
 3. Salmonellosis. "Paratyphoid nodules" (areas of granulomatous inflammation)
- E. Parasitic causes
 1. *Ascaris suum* larval migration in pigs. "Milk spots" (whitish areas of fibrosis) on capsular and cut surfaces
 2. *Taenia* spp. larval cestodes. Parasitic cysts in liver of intermediate host
 3. Trematodes (flukes) in sheep and cattle. Black friable areas or tracts associated with fluke migration and detritus

VIII. Neoplasia of the liver
- A. Common site of metastasis, especially of primary abdominal neoplasms
- B. Primary neoplasms of liver include the following:
 1. Hepatocellular adenoma (most common in young ruminants)
 2. Hepatocellular adenocarcinoma (most frequent in sheep)
 3. Cholangiocellular (bile duct) adenoma (common in cats)
 4. Cholangiocellular carcinoma. Firm, raised, tan, with umbilicated centers (of necrosis)
 5. Hemangiosarcoma of dogs. Along with right atrium and spleen, liver is common site of occurrence

IX. Conditions of the biliary system
- A. Cholelithiasis
 1. Choleliths ("gallstones") are infrequent in animals
 2. Described most commonly in ruminants
 3. Concretions of normally soluble components of bile
- B. Cholecystitis
 1. Edema and hemorrhage seen with infectious canine hepatitis virus infection
 2. Fibrin and edema with salmonellosis in calves
- C. Cystic mucinous hyperplasia of the gallbladder in dogs and sheep
 1. Excess mucus and cobblestone lining
 2. Unknown cause

EXAMINATION OF THE URINARY TRACT

I. Kidneys
- A. Necropsy examination
 1. Renal capsules should be stripped to evaluate lesions in subcapsular surface that might not otherwise be visible
 2. Cut kidneys longitudinally to evaluate cortices, medullae, and renal pelvises or papillae
 3. Feline kidneys are normally light brown or tan because of lipid in tubular epithelial cells
- B. Development defects
 1. Renal hypoplasia
 a. Unilateral or, if bilateral, more severe on one side
 b. Pigs, most commonly
 2. Renal dysplasia (juvenile nephropathy)
 a. Certain breeds of dogs
 b. Kidneys may be irregularly shaped or asymmetric in size
 3. Polycystic kidneys. Can be inherited in pigs, lambs, Persian cats (Figure 7-6)
- C. Renal infarcts
 1. Kidneys are common sites of infarction because of single-type ("end artery") blood supply
 2. Wedge-shaped lesions, with their base at capsular surface and apex toward medulla
 3. Most infarcts are "pale" or white to tan because of arterial occlusion
 4. "Red" infarcts may be due to venous occlusion
 5. Shrunken, gray-white capsular surface implies chronicity
- D. Renal degeneration and necrosis
 1. Tubular nephrosis or "toxic nephrosis: Kidneys are swollen and paler than normal
 2. Papillary or medullary crest necrosis
 a. Associated with ischemia
 b. Friable, yellow-gray to green
- E. Inflammation of the kidneys
 1. Glomerulonephritis
 a. Diffusely light brown color, granular texture
 b. Kidneys may also be enlarged

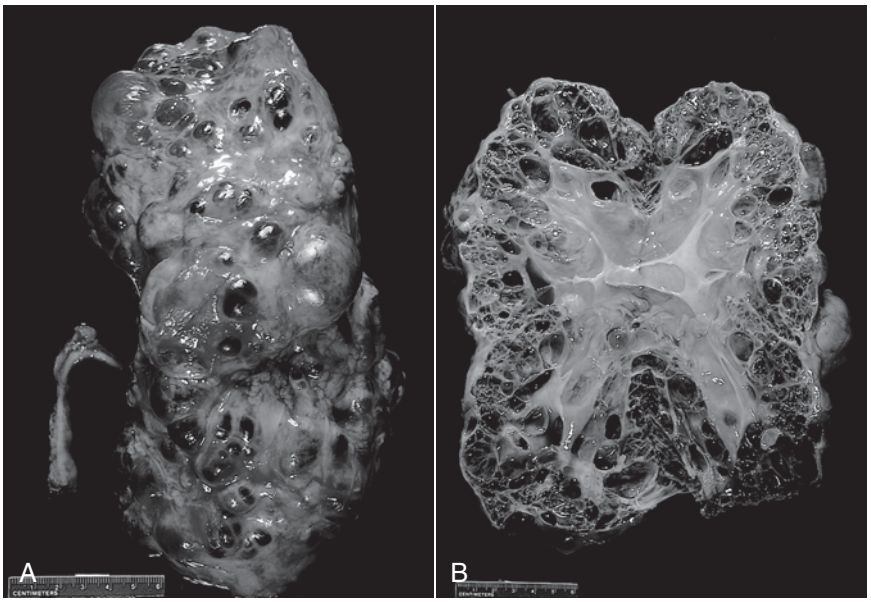


Figure 7-6 Autosomal-dominant adult polycystic kidney viewed from the external surface **(A)** and bisected **(B)**. The kidney is markedly enlarged (note the centimeter rule) with numerous dilated cysts. (From Kumar V, Cotran RS, Robbins SL. *Robbins Basic Pathology,* 8th ed. Philadelphia, 2008, Saunders.)

2. Embolic nephritis (suppurative glomerulitis)
 a. White foci scattered throughout kidneys
 b. Secondary to bacteremia
3. Interstitial nephritis
 a. Multifocal to diffuse
 b. Mottled color, with red areas if acute
 c. Gray-white areas with irregular scarring of capsular surface if chronic
4. Pyelonephritis
 a. Inflammation of renal pelvis and renal parenchyma
 b. Ascending urinary tract infection
 c. Inflammation most severe at renal pelvis, but there may be an irregular and patchy distribution
 i. May include exudate in pelvis or ureter
 ii. May be concomitant hydronephrosis

F. Amyloidosis
1. Grossly, kidneys are enlarged, waxy in texture, and lighter color than normal
2. Histologically, deposits are in glomeruli and medullary interstitium

G. Neoplasia
1. Renal adenoma: Rare
2. Renal carcinoma: Most common primary renal neoplasm and most common in dogs
3. Renal lymphosarcoma in cats and cattle
 a. Part of multicentric lymphosarcoma
 b. Differential diagnosis in cats is granulomas associated with FIP virus infection
4. Nephroblastoma (embryonal nephroma)
 a. May be recognized at slaughter in pigs and chickens
 b. Seen less frequently in cattle and dogs
 c. Neoplasms of young animals

II. Lower urinary tract

A. Ectopic ureter
1. Most frequently in dogs
2. Ureter empties into urethra, vagina, neck of bladder, vas deferens, prostate gland, or other secondary sex gland
3. Subject to obstruction or infection and thus predispose animal to pyelitis or pyelonephritis

B. Patent urachus
1. Most common malformation of the urinary bladder
2. Channel between bladder's apex and the umbilicus
3. Foals most commonly affected
4. Prone to bladder infection

C. Urolithiasis
1. Urinary calculi
 a. Can be small or large, single or multiple, smooth or rough, variably shaped, various colors
 b. Can be found in urinary bladder, renal pelvises or calyces, ureters, or urethra
 c. Composed of salts of inorganic or organic acids (e.g., struvite: magnesium ammonium phosphate hexahydrate) or other materials such as cystine or xanthine
2. Obstruction from calculi is more common in males than females
 a. Male cattle: Urethral calculi lodge at ischial arch and proximal end of sigmoid flexure
 b. Rams and wethers: Calculi lodge in urethral process (vermiform appendage)
 c. Male dogs: Urethral calculi lodge proximal to base of penis
 d. Feline urologic syndrome: Sandlike struvite crystals mix with inflammatory debris and can fill entire urethra
3. Obstruction not common in horses, but sandlike crystals precipitate as sludge in urinary bladder (sabulous urolithiasis)

D. Acute cystitis
1. Urinary bladder wall is red, with or without hemorrhage into urine
2. Bacterial infection is most common cause in all species
a. Uropathogenic *E. coli* in all species
b. *Corynebacterium renale* in cattle
c. *Eubacterium suis* in pigs
d. *Klebsiella* spp. in horses
3. Chemical causes
a. Cyclophosphamide in dogs
b. Bracken fern ingestion in cattle
c. Cantharidin (blister beetle) poisoning in horses

E. Chronic cystitis: Thickened bladder wall, with cobblestone mucosa (transitional cell hyperplasia, goblet cell hyperplasia, lymphoid follicle formation)

F. Neoplasia: Transitional cell papilloma or carcinoma of urinary bladder
1. Most common in dogs
2. Trigone area of bladder

EXAMINATION OF THE PANCREAS

I. Exocrine pancreas
A. Pancreatic hypoplasia
1. Seen sporadically in calves
2. Scant pancreatic tissue difficult to identify

B. Juvenile pancreatic atrophy
1. Several dog breeds, especially German shepherd
2. Young dogs, 6 to 12 months old
3. Small volume of pancreatic tissue

C. Acute pancreatitis
1. Dogs, most commonly
2. Pancreas is red, edematous, with dark red to black areas of hemorrhage
3. Possibly friable because of necrosis
4. White, chalky areas of fat necrosis in peripancreatic mesentery

D. Chronic pancreatitis
1. Most common in dogs
2. Result of multiple bouts of acute pancreatitis
3. Areas of fibrosis (gray-white) and pancreatic atrophy

E. Nodular hyperplasia of the exocrine pancreas
1. White nodules in older dogs and cats
2. Generally, an incidental finding

F. Carcinoma or adenocarcinoma of exocrine pancreas in dogs and cats

II. Endocrine pancreas
A. No pancreatic lesions can be definitely attributed to endocrine pancreas based on gross examination

B. Islet cell adenomas (insulinomas) associated with hypoglycemia. Single tan to red nodules

EXAMINATION OF THE ENDOCRINE SYSTEM

I. Pituitary gland: Adenoma of pars intermedia
A. Horses
1. Enlargement of pituitary gland to 2 to 3 times normal size
2. On cut section, enlargement is seen to be due to a nodular mass in pars intermedia
3. Associated with pituitary pars intermedia dysfunction

B. Dogs: Associated with Cushing disease

II. Adrenal glands
A. Nodular cortical hyperplasia
1. Older dogs, horses, ferrets, cats
2. Tan to yellow nodules in cortex or on capsule
3. Usually an incidental finding

B. Adrenocortical adenomas and carcinomas
1. Most common in dogs and ferrets
2. May be functional and associated with Cushing disease in dogs
3. Associated with hyperestrogenism in ferrets

C. Diffuse thickening of the adrenal cortices grossly may be seen in association with adrenocorticotropic hormone (ACTH)-producing pituitary adenoma

D. Hypoadrenocorticism (Addison disease)
1. Very thin adrenal cortices with relatively prominent medullae
2. Overall size of adrenal glands is small

E. Adrenal medullary hyperplasia
1. Precedes development of pheochromocytoma in bulls
2. Increased adrenal gland weight and decreased corticomedullary thickness ratio

F. Pheochromocytoma
1. Dogs and cattle
2. Develop concurrently with C cell neoplasms of thyroid gland in bulls
3. Large, gray-red, soft masses that replace/obscure most of the affected gland
4. Highly invasive into surrounding structures (e.g., caudal vena cava); metastasize readily

G. Neuroblastoma
1. Large intra-abdominal masses originating in ganglia near adrenal gland
2. Young animals

III. Thyroid gland
A. Hypothyroidism: Whether due to follicular atrophy or lymphocytic thyroiditis, the thyroid gland is smaller than normal, and often difficult to identify

B. Thyroid follicular hyperplasia
1. Congenital iodine deficiency (“goiter”)
2. Congenital dyshormonogenetic goiter in certain breeds of sheep and goats
3. Enlarged thyroid gland associated with dystocia
4. Multinodular follicular hyperplasia common in older horses

C. Feline hyperthyroidism
1. Multinodular or irregularly shaped, enlarged thyroid lobes
2. Hyperplasia or adenomas histologically

D. Follicular cell carcinoma
1. More common in dogs than cats
2. Readily invade surrounding structures (esophagus, trachea) and readily metastasize to lungs

E. C-cell (calcitonin-secreting) neoplasms. Most frequent in older bulls

IV. Parathyroid glands. Hyperparathyroidism
 A. Nutritional: inadequate vitamin D or calcium, excess phosphorus
 B. Renal: Response to hypocalcemia
 C. Primary: Adenoma or carcinoma of parathyroid gland
 D. Pseudohypercalcemia of malignancy
 E. In the first three types, see gross enlargement of one or more parathyroid glands
V. Other endocrine neoplasms
 A. Gastrin-secreting islet cell neoplasms of pancreas
 B. Chemoreceptor neoplasms (chemodectomas). Carotid and aortic body tumors
 1. Base of the heart
 2. Especially in brachycephalic breeds of dogs
 3. Adenomas or carcinomas
 C. Ectopic thyroid neoplasms at base of the heart

EXAMINATION OF THE HEMATOPOIETIC SYSTEM

I. Spleen
 A. "Storage" spleen
 1. Relatively large with abundant smooth muscle trabeculae and capacity to store erythrocytes but relatively little lymphoid tissue
 2. For example, in dogs, cats, cattle, horses
 B. "Defense" spleen
 1. Relatively small, with abundant lymphoid tissue and relatively little smooth muscle trabeculae
 2. For example, in rabbits
 C. Cattle and horses have relatively abundant fibrous tissue in splenic capsule, giving it a white or gray appearance
 D. Splenic atrophy
 1. Age-related
 2. Associated with cachexia
 3. Associated with viral infections that destroy lymphocytes (e.g., BVD virus)
 4. Spleen is small and firm with shriveled capsule
 E. Splenomegaly
 1. Associated with congestion:
 a. Animals euthanized with barbiturates
 b. Torsion
 c. Acute hemolytic anemia
 d. Septicemia or enterotoxemia
 e. Spleen oozes blood on cut section
 2. Associated with cell proliferation
 a. Lymphoid hyperplasia. May see white foci on cut section
 b. Chronic hemolytic anemia
 c. Extramedullary hematopoiesis
 d. Splenitis. May see white foci on cut section
 e. Diffuse neoplastic cell infiltration. Myeloproliferative neoplasms, mast cell leukemias
 F. Nodules in the spleen
 1. Nodular lymphoid hyperplasia
 a. Dark red to purple, firm nodules
 b. Common in older dogs
 2. Hematoma. Dark red, blood-filled nodules
 3. Hemangioma, hemangiosarcoma. Red to dark red, blood-filled to firm nodules
 4. Lymphosarcoma
 a. Tan, homogeneous, firm nodules, or diffuse involvement
 b. Cattle, cats, dogs, horses
 5. Implantation of abdominal neoplasms on splenic capsule but do not commonly find metastasis within splenic parenchyma
 G. Hemosiderotic plaques
 1. Firm to gritty, pale yellow to yellow brown plaques along margins of spleen
 2. Believed to be associated with incidental trauma
II. Thymus
 A. Involutes with sexual maturity, replaced gradually by loose connective tissue
 B. Thymic hypoplasia in animals with inherited immune deficiencies (e.g., severe combined immunodeficiency (SCID) in Arabian foals and Parson Russell terriers)
 C. Thymic atrophy associated with virus infection (e.g., feline leukemia virus and feline immunodeficiency virus), certain toxins, or malnutrition
 D. Thymic lymphosarcoma. T-lymphocyte neoplasm of young animals (especially cats and cattle)
 E. Thymoma
 1. Neoplasm, primarily of thymic epithelial cells
 2. Slow growing and uncommon
 3. May be associated with myasthenia gravis and megaesophagus in dogs
III. Lymph nodes
 A. Enlargement due to lymphoid hyperplasia or lymphadenitis
 1. White foci on cut section may be areas of hyperplasia, neutrophil accumulation (abscesses), or macrophage accumulation (granulomas)
 2. Hyperemia and edema may contribute to enlargement in acute lymphadenitis
 B. Caseous lymphadenitis of sheep and goats
 1. *Corynebacterium pseudotuberculosis*
 2. Caseous, white to pale green laminated abscesses on cut section
 C. Other infectious diseases that target the monocyte-macrophage system
 1. Histoplasmosis (*Histoplasma capsulatum*)
 2. Porcine circovirus infection
 D. Lymphosarcoma. Nodal architecture is effaced by tan, homogeneous, firm tissue
IV. Bone marrow
 A. Marrow cavities of long bones may be evaluated for hematopoiesis. Red areas at junction of cortical and trabecular bone and near metaphyses are normally sites of hematopoiesis
 B. Myeloproliferative disorders
 1. Neoplastic proliferations of erythroid, myeloid, or monocytic cell types
 2. Irregular, mottled areas in marrow cavities
 3. Entire marrow cavity may be filled with firm, mottled neoplastic tissue
 4. May be areas of bone lysis

EXAMINATION OF THE REPRODUCTIVE TRACT

I. Females
 A. Ovaries
 1. Lesions related to estrus cycle changes include the following:
 a. Follicular hemorrhage
 b. Atretic follicles
 c. Follicular cysts
 d. Cystic corpora lutea
 e. Supernumerary follicles
 2. Neoplasms
 a. Dysgerminoma
 (1) Solid, lobulated mass with areas of hemorrhage and necrosis
 (2) Rare, but seen in bitches, sows, cows, mares
 b. Teratoma
 (1) Well-differentiated tissues from at least two of the three embryonic germ layers (endoderm, mesoderm, ectoderm)
 (2) Often find areas of skin, hair, bone, etc.
 (3) Rare, but especially in mares
 c. Granulosa cell tumor: Most common ovarian neoplasm in large animals
 d. Cystadenoma or cystadenocarcinoma of surface epithelium: Most common in bitches
 B. Uterus
 1. Torsion in pregnant animals. Most commonly in cattle, but also in bitches and queens
 2. Endometritis
 a. Redness indicates acute inflammation
 b. Thickening of mucosa without redness may indicate chronic inflammation
 3. Pyometra: Suppurative exudate in uterus
 4. Endometrial hyperplasia
 a. Cystic or cobblestone appearance of endometrium
 b. Especially in bitch and ewe
 5. Neoplasia: Not common, except for lymphosarcoma in cattle and endometrial adenocarcinoma in rabbits
 C. Mammary gland: Mastitis
 1. Important primarily in cows
 2. Most causes are bacterial
 a. Mammary gland is principal site of persistence or reservoir for *Streptococcus agalactiae*, *Staphylococcus aureus*, and *Mycoplasma bovis*
 b. Environment is reservoir for coliforms
 c. Overlap group contains many other bacteria
 3. Inflamed gland is firm rather than spongy
 4. Color of affected tissue may vary from dark pink to dark red to green-black
 5. Examine nature (color, consistency) of milk from each quarter at necropsy. Watery, serous, thicker than normal, presence of flakes
II. Males
 A. Testes
 1. Cryptorchidism
 a. Incomplete descent into scrotum
 b. Unilateral or bilateral
 c. Cryptorchid testis(es) smaller than normal
 2. Orchitis
 a. Affected testis may or may not be swollen
 b. Soft white to yellow foci on cut section initially
 c. Firm, white foci on cut section in chronic stages
 d. Causes include the following:
 (1) Bulls: *Brucella abortus*, *Arcanobacterium pyogenes*, bluetongue virus
 (2) Rams: *Brucella ovis*, *Corynebacterium ovis*
 (3) Stallions: Equine infectious anemia virus, equine viral arteritis virus
 (4) Dogs: *Brucella canis*
 3. Neoplasia
 a. Seminoma
 (1) Dog, stallion
 (2) White to pink gray, firm, bulging on cut section
 (3) Cause testicular enlargement
 (4) Seldom malignant
 b. Leydig cell (interstitial cell) tumor
 (1) Dog, bull
 (2) Tan to orange, soft
 (3) Usually does not cause testicular enlargement
 (4) Almost always benign
 c. Sertoli cell tumor
 (1) Dog
 (2) Firm, white, lobulated, fibrous bands
 (3) May or may not cause testicular enlargement
 (4) If estrogen-producing → feminization syndrome (gynecomastia), bone marrow toxicity
 B. Prostate gland
 1. Prostatitis
 a. Acute, chronic, forms with abscess formation, and forms with specific causes like *B. canis*
 b. May be asymmetric enlargement of prostate gland
 c. May preputial discharge
 d. Often accompanies hyperplasia
 2. Prostatic hyperplasia
 a. Symmetric glandular enlargement in intact older dogs
 b. Texture of gland remains spongy, as in normal gland
 c. May have cystic areas visible on cut section
 3. Prostatic adenocarcinoma
 a. Dogs, but generally uncommon
 b. Asymmetric, firm mass
 C. Penis and prepuce
 1. Inflammation
 a. Balanitis: Inflammation of glans penis
 b. Posthitis: Inflammation of prepuce
 c. Balanoposthitis: Inflammation of penis and prepuce
 d. Some causes

(1) Bull. Bovine herpesvirus type 1: Pustules
(2) Stallion. Equine herpesvirus type 3
(a) Coital exanthema
(b) Pustules
(3) Ram. *Corynebacterium renale*: Ulcers

2. Neoplasia
a. Squamous cell carcinoma: Horse, dog
b. Papilloma or fibropapilloma in bulls
c. Transmissible venereal tumor in dogs. Usually on proximal, rather than distal penis

III. Abortion cases
A. Examination of the placenta
1. Retained fetal membranes
a. In a cow, membranes should be expelled within 12 hours of birth of the calf
b. Retained membranes can be source of infection and inflammation (endometritis)
2. Chorioallantois
a. Normally smooth on allantois side and velvety on chorionic side
b. Thickening of chorioallantois may indicate inflammation or edema
c. Rough, friable appearance of chorion indicates necrosis
d. Color is normally pink to red
e. Brown or dark red may indicate inflammation
f. Hydroallantois: Excessive allantoic fluid. Seen primarily in cows
3. Amnion
a. Contains viscous, clear fluid
b. Hydramnios: Excessive volume of amnionic fluid. Seen primarily in cows
c. Amnionic plaques
(1) Tan to yellow, firm plaques of stratified squamous epithelium
(2) Incidental finding in cattle, seen less frequently in mares

B. Abortion: General concepts
1. Twinning: Common cause of abortion in mares
2. Umbilical cord torsion
a. Cause of abortion primarily in horses
b. Edema and hemorrhage of the cord
3. Fetal mummification: Most common with twin pregnancy in mares and parvovirus infection in sows
4. Fetal maceration or disintegration
a. Requires presence of bacteria in the uterus
b. The bacteria could have caused the abortion or may have entered uterus after the death of the fetus
5. Bacterial abortion
a. Organism can reach fetus via bloodstream of dam or through reproductive tract (cervix to uterus)
b. Almost any bacterium that causes septicemia can infect pregnant uterus and fetus
c. Bacteria that target the placenta or fetus or both include the following:
(1) *Campylobacter fetus* var. *venerealis* (cattle)
(2) *Campylobacter fetus* subsp. *fetus* (sheep)
(3) *Brucella* spp. ((cattle, sheep, pigs, dogs)
6. Viral abortion
a. Systemic infection of fetus via bloodstream of dam
b. Herpesviruses of cattle (IBR virus), horses (EHV-1), pigs (pseudorabies), goats (caprine herpesvirus), and dogs (canine herpesvirus) associated with abortion
7. Fungal abortion
a. In cattle, organism typically spreads hematogenously to the fetus
b. In horses, organism typically enters uterus through cervix
8. Protozoal abortion
a. *Toxoplasma gondii* in sheep
b. *Tritrichomonas foetus* in cattle
c. *Neospora caninum* in cattle

EXAMINATION OF THE CENTRAL NERVOUS SYSTEM

I. Brain
A. Generally, no cutting is done of the fresh brain at necropsy except to collect necessary samples for microbiologic tests, rabies testing
1. Examine brain for symmetry. Asymmetry may indicate abscess or neoplasm
2. Leptomeninges should be transparent and thin. Cloudy meninges may indicate inflammation. Fluid nature of suppurative exudate may be appreciated with digital pressure

B. Developmental defects
1. Hydrocephalus
a. Noncommunicating
(1) Blockage or malformation cranial to lateral aperture of fourth ventricle
(2) Dilation of lateral ventricles and possibly third ventricle
b. Communicating
(1) Blockage or malformation past lateral aperture of fourth ventricle
(2) Dilation of entire ventricular system and subarachnoid spaces
2. Hydranencephaly
a. Thin cerebral cortices due to necrosis or lack of tissue development
b. Compensatory dilation of lateral ventricles
c. In utero viral infection (e.g., BVD virus) is most common cause
3. Cerebellar hypoplasia
a. Cerebellum is normally about 10% of total brain weight
b. Common causes of hypoplasia: viral (e.g., feline panleukopenia virus, BVD virus)

C. Hemorrhage
1. Trauma is most common cause. May be epidural, subdural, or leptomeningeal
2. Other causes include vasculitis caused by viral or bacterial infection
a. Usually leptomeningeal hemorrhage
b. Petechiae or ecchymoses

D. Edema
 1. Swollen cerebral gyri, wet leptomeninges
 2. If severe, there may be herniation of the cerebellum through the foramen magnum
 3. Vasogenic (vascular related) or cytotoxic (cell metabolism related) causes

E. Degeneration and necrosis. Areas of discoloration (yellow, red, brown) or softening (malacia)
 1. Leukoencephalomalacia: Softening or necrosis of white matter of the brain
 2. Polioencephalomalacia: Softening or necrosis of gray matter of the brain. May fluoresce under ultraviolet light

F. Inflammation (encephalitis)
 1. Areas of discoloration or softening. Nonspecific regarding agent
 2. Petechiae and ecchymoses, depending on causative agent

G. Neoplasia
 1. Glial cell neoplasms (e.g., astrocytoma, oligodendroglioma) most common primary brain neoplasm in dogs. Gray to pink, soft, usually ill-defined mass
 2. Meningioma most common in cats. White to tan, firm, usually discrete mass

II. Spinal cord

A. Examine vertebrae for fractures, subluxations, intervertebral disc disease

B. Developmental defects: Spina bifida
 1. Dorsal defect in one to several vertebrae
 2. Often associated with spinal cord malformation(s), such as:
 a. Meningocele: protrusion of meningeal sac through defect
 b. Meningomyelocele: Protrusion of meningeal sac and deformed spinal cord through defect
 3. Equivalent of spina bifida in brain is cranium bifidum

C. Hemorrhage
 1. Associated with trauma (e.g., acute intervertebral disc extrusion, fracture)
 2. Associated with viral or bacterial infection: Petechiae and ecchymoses

D. Degeneration and necrosis
 1. Myelomalacia: Softening or necrosis of the spinal cord
 2. Often no gross lesions with degenerative diseases or conditions caused by toxins

E. Inflammation (myelitis)
 1. Areas of discoloration, as described for brain
 2. Petechiae and ecchymoses

F. Neoplasia: Primary neoplasia of spinal cord is rare

Supplemental Reading

King JM, Dodd DC, Newson ME, Roth L. *The Necropsy Book*. Ithaca, NY, 1989, Arnold Printing Corporation.

McGavin MD, Zachary JF, eds. *Pathologic Basis of Veterinary Disease,* 4th ed. St Louis, 2007, Mosby.

Ophthalmology

8 CHAPTER

Wendy M. Townsend

EXAMINING THE EYE

I. Diagnostic tests
 A. The Schirmer tear test I (STTI): Allows quantification of the production of the aqueous tear phase
 1. Measures basal plus stimulated tear production
 2. Must be performed before the application of any drops or topical anesthetic
 3. Measure how far tears travel along the strip from the notch in 1 minute
 4. Normal results can range from 15 to 25 mm/minute
 5. Less than 10 mm/minute is suspicious of reduced tear production
 6. Less than 5 mm/minute is diagnostic of dry eye
 B. The Schirmer tear test II
 1. Measures basal tear production
 2. Performed after anesthetizing the cornea with proparacaine and drying the excess fluid from the conjunctival sac
 3. Performed as for STTI
 4. STTII reading ≈ 50% of STTI reading
 C. Fluorescein staining
 1. Administer from sterile, single-use impregnated paper strips (or single-use vials)
 2. Moisten the strip with artificial tears or sterile saline and apply a small amount over the dorsal bulbar conjunctiva
 3. Do not touch the cornea to avoid misleading stain deposition
 4. Flush eye with sterile saline to prevent a false impression of stain uptake
 5. In the presence of an epithelial defect, fluorescein stains the stroma bright green
 D. Measurement of intraocular pressure (IOP)
 1. Normal is 15 to 25 mm Hg
 2. Digital assessment of IOP: Very unreliable and inaccurate
 3. The Schiøtz tonometer: Operates on the principle that the amount of indentation of a given area of the cornea is proportional to the IOP
 4. Applanation tonometers measure the pressure required to flatten a given area of the corneal surface (this pressure is proportional to the IOP). The most commonly used applanation tonometer is the Tonopen

II. Basic ocular anatomy
 A. Eyelids
 1. Protect the globe
 2. Distribute the tear film
 3. Produce the lipid layer of the tears
 4. Drainage of the tear film
 B. Third eyelid (nictitating membrane, nictitans)
 1. T-shaped cartilage skeleton
 2. Nictitans gland produces part of the aqueous portion of tears
 C. Tear film
 1. Oily outer layer produced by meibomian glands
 2. Aqueous layer (main portion) produced by lacrimal and nictitans glands
 3. Inner mucoid layer produced by conjunctival goblet cells
 D. Drainage of the tears
 1. Lacrimal puncta at medial canthus of upper and lower eyelids
 2. Canaliculi from puncta to lacrimal sac
 3. Nasolacrimal duct empties into the nose at the nasal ostium
 E. Globe: The wall of the globe itself consists of three main tunics (layers)
 1. The outer fibrous wall (cornea and sclera)
 2. A middle vascular coat: The uveal tract (iris, ciliary body, choroid)
 3. An inner neuroepithelial layer (retina = retinal pigment epithelium + neurosensory retina)

DISEASES OF THE ORBIT

I. Anatomy of the orbit
 A. Bony structure
 1. Maxillary, frontal, lacrimal, zygomatic, sphenoid, and palatine bones
 2. Herbivores have "closed" orbit with bone 360 degrees around orbital circumference
 3. Dogs, cats, and others have "open" orbit with supraorbital ligament at lateral aspect
 B. Extraocular muscles
 1. Dorsal, medial, ventral, and lateral rectus muscles
 2. Dorsal and ventral oblique muscles
 3. Retractor bulbi muscles

II. Conditions that affect the orbit
 A. Abcesses and cellulitis
 1. Acute onset unilateral exophthalmos

2. Pain is apparent on opening of mouth
3. Causes: Trauma, foreign body, fungal or parasitic infections, tooth-root abscess, sinus infection, inflammation of zygomatic salivary gland (often associated with a mucocele)
4. Diagnostics: Complete blood cell count (CBC), serum chemistry. Orbital ultrasound. Dental examination with or without radiographs. Fine needle aspiration (FNA) through oral mucosa behind last molar
5. Treatment: Drain abscess + systemic antibiotics

B. Orbital neoplasia
1. Presentation: Gradual onset, slowly progressive exophthalmos
2. Usually nonpainful when manipulating mouth
 a. Occassionally enophthalmos
 b. Older animals
3. 90% are malignant
4. Diagnostics: Ultrasound, orbital computed tomography (CT) or magnetic resonance imaging (MRI), and FNA with cytology
5. Treatment: Surgical excision often enucleation with extenteration of the orbit or partial or complete orbitectomy is required
6. Prognosis: Poor

C. Orbital trauma: Traumatic proptosis
1. Presentation: Eyelids trapped behind the equator of the globe
2. Treatment
 a. Globes deemed nonreplaceable should be enucleated
 b. Globes to be replaced should be replaced with a temproary tarsorraphy under general anesthesia
3. Prognosis
 a. 20% to 30% chance of vision following proptosis
 b. 50% to 60% chance of globe replacement with or without vision

DISORDERS OF THE EYELIDS

I. Structural or functional abnormalities
A. Agenesis (coloboma): A congenital defect in cats and horses
1. Cats: Upper temporal eyelid (lateral 1/3 to 2/3) fails to develop
2. Absence of eyelids results in secondary trichiasis and exposure keratoconjunctivitis

B. Ankyloblepharon: Adhesion of the eyelid margins to each other
C. Dermoid: A choristoma (normal tissue in an abnormal location)
D. Entropion: Inversion of the eyelid margin (usually results in secondary trichiasis)
1. Causes hairs to rub on cornea (secondary trichiasis)
2. Correct surgically with a modified Hotz-Celsus excision

E. Ectropion: Eversion of the eyelid margin

II. Eyelash abnormalities
A. Distichiasis: Cilia arise from meibomian gland openings
B. Districhiasis: More than one hair emanates from a meibomian gland opening
C. Ectopic cilia: Hair erupts through the palpebral conjunctiva
D. Trichiasis: Hair in normal location but misdirected toward the globe

III. Blepharitis: Inflammation of the eyelids
A. Bacterial: Most commonly *Staphylococcus intermedius*
B. Parasitic: Mites (e.g., *Demodex* or *Sarcoptes* in young dogs, *Notoedres* in cats, face flies and habronemiasis in horses)

IV. Neoplastic eyelid diseases
A. Canine
1. Benign
2. Meibomian gland adenoma most common

B. Feline
1. Malignant
2. Squamous cell carcinoma most common

C. Equine
1. Sarcoid: Locally invasive and fibroblastic neoplasm. Usually affect horses younger than 7 years of age
2. Squamous cell carcinoma: Predilection for horses with light circumocular pigmentation

D. Bovine: Squamous cell carcinoma, the most common eyelid neoplasm of cows

DISORDERS OF THE CONJUNCTIVA

I. Anatomy and physiology
A. The conjunctiva is a mucous membrane that lines the posterior aspects of the eyelids, the nictitating membrane, and the sclera before terminating at the limbus (corneoscleral junction)
B. Functions of the conjunctiva
1. Protective covering of the eye and adnexa
2. A source of the mucus portion of the tear film (via goblet cells)
3. First line of defense against potential pathogens (via conjunctival associated lymphoid tissue)

II. Congenital abnormalities: Dermoid (a choristoma) normal elements of skin in an abnormal location
A. Aberrant dermis affecting conjunctiva and/or cornea (sometimes also eyelids)
B. Appears as an elevated, often pigmented mass, usually bearing hairs
C. Surgical excision is curative

III. Neonatal disease. Neonatal conjunctivitis (ophthalmia neonatorum)
A. Infection before lid separation; often bacterial in puppies and viral or chlamydial in kittens
B. Treatment: Separate lids, flush with sterile saline, apply broad-spectrum antibiotic ointment four times daily in dogs, tetracycline in kittens
C. Sequelae: Symblepharon (conjunctival adhesion to adjacent tissues), corneal perforation, fibrosis, blindness

IV. Conjunctivitis
A. Canine conjunctivitis
1. Bacterial: Rare
2. Secondary causes

a. Conformational lid abnormalities (e.g., entropion, ectropion, trichiasis, lid tumors)
b. Spread of infection from elsewhere (e.g., skin, ears, lips)
c. Tear film abnormalities: Keratoconjunctivitis sicca (dry eye)
d. Irritants: Chemicals, dust
3. Viral: Canine distemper
4. Allergic or hypersensitivity

B. Feline conjunctivitis
1. Feline herpesvirus 1 (FHV-1) is the most common cause
2. *Chlamydophila felis* may cause conjunctivitis as well. Treat with tetracycline or doxycycline
3. *Mycoplasma felis:* Opportunistic. Treat with topical tetracycline

DISORDERS OF THE NICTITATING MEMBRANE

I. Anatomy
A. T-shaped cartilage
B. Nictitans gland at base
C. Responsible for 30% to 40% of aqueous tears
D. Movement is passive protrustion

II. Abnormalities
A. Eversion or inversion of the cartilage
1. Most common in large breeds
2. Scroll-like curling of the cartilage

B. Prolapsed gland of the third eyelid (Figure 8-1)
1. Weak connective tissue
2. Replace by tacking to orbital rim or pocket technique
3. Do *not* remove or risk decreased tear production

DISEASES OF THE CORNEA

I. Anatomy
A. Layers of the cornea
1. Tear film
2. Epithelium
3. Basement membrane
4. Stroma
5. Descemet membrane: Does not take up fluorescein stain
6. Endothelium

B. Corneal response to insult
1. Edema: Loss of epithelial or endothelial layers lead to edema. Fluid accumulation
2. Vacularization: Normal cornea does not have blood vessels
3. Pigmentation: It can arise from chronic corneal irritation

C. Keratitis: Inflammation of the cornea

II. Keratoconjunctivitis sicca (KCS; dry eye)
A. Inflammation of the cornea and conjunctiva as a result of low aqueous component of the tear film
B. Causes
1. Immune-mediated destruction of the tear-producing glands: Most common cause (usually bilateral)
2. Congenital: Gland aplasia (unilateral or bilateral)
3. Iatrogenic: Excision of nictitans gland (unilateral or bilateral) plus later loss of lacrimal gland function
4. Drug induced: Sulfa drugs, etogesic (usually bilateral)
5. Trauma: Often follows prolpase or proptosis of the globe (usually unilateral)
6. Neurogenic: Interference with nerve supply to glands (usually unilateral)
7. Following infection: Distemper in dogs, herpesvirus in cats (unilateral or bilateral)

C. Clinical signs of KCS
1. Ocular irritation or pain
2. Conjunctivitis
3. Ocular discharge
4. Keratitis

D. Diagnosis of KCS
1. Clinical signs (see above)
2. Schirmer tear test readings

E. Treatment of KCS
1. Reduce immune destruction of tear producing glands: Cyclosporine
2. Stimulate tear production: Oral pilocarpine
3. Parotid duct transposition: Moving the parotid duct so that it opens into the lower conjunctival fornix

III. Ulcerative keratitis
A. Investigation of corneal ulcer
1. Fluorescein stain: Show presence of ulcer and demonstrate extent
2. Judge depth of ulcer. *Note:* Descemet's membrane does not stain with fluorescein
3. Swab from edge of ulcer crater for culture (bacterial, or fungal in some cases)
4. Smear from edge of ulcer for cytology

B. Superficial corneal ulcers
1. Treat initially with a broad-spectrum antibiotic
2. Typically, superficial ulcers heal within 3 to 5 days. If the ulcer has not resolved in 3 to 5 days
a. The cause for the ulcer is still present



Figure 8-1 Cherry eye in a 2-year-old American cocker spaniel. Note the intumescent, hyperemic appearance of the gland, which can be seen through the bulbar surface of the third eyelid conjunctiva. (From Dziezyc J, Millichamp NJ. *Color Atlas of Canine and Feline Ophthalmology.* St Louis, 2005, Saunders.)

b. The ulcer is infected (see below)
c. An indolent ulcer is present (see below)

3. Slow-healing (indolent) ulcers in dogs. These are common in dogs and are due to a failure of the epithelium to adhere to the basement membrane. Management:
 a. Debridement and grid keratotomy: First line of treatment
 b. If ulcer does not heal in 2 to 3 weeks, repeat
 c. If ulcer does not heal, can do a superficial keratectomy
 (1) Requires general anesthesia and magnification
 (2) Surgical removal of superficial layer of cornea includes removal of epithelium, basement membrane, and very thin layer of corneal stroma
4. Slow healing (indolent) ulcers in cats
 a. Often associated with feline herpesvirus infection
 b. Do not perform grid keratotomy, which may lead to corneal sequestrum formation
5. Slow healing (indolent) ulcers in horses
 a. Often superficial fungal infections
 b. Do not perform a grid keratotomy; debriding loose epithelium is acceptable

C. Midstromal corneal ulcer
1. Potentially more serious
2. Watch carefully
3. Perform culture and cytology
4. Antibiotics should be given frequently if ulcer is infected (e.g., initially every 2 hours)
5. 1% atropine to dilate the pupil as needed but not more than 4 times daily

D. Deep ulcers or descemetoceles
1. Perforation can occur, so treat as an emergency
2. Usually require surgical repair
 a. Conjunctival pedicle flap is preferred technique. It provides a blood supply to the defect for healing and physical protection to seal the defect
 b. If surrounding cornea is healthy and not infected or melting, a corneoscleral transposition can be performed

E. Herpesvirus keratitis (FHV-1)
1. Common in cats
2. Conjunctivitis with or without corneal ulcer
3. Symblepharon conjunctival adhesions are common sequelae
4. Treatment
 a. Topical antiviral medication (idoxuridine or trifluridine; Viroptic)
 b. Topical α-interferon has questionable efficacy
 c. L-lysine orally administered may help reduce frequency of recrudescence

F. Corneal fungal infection (mycosis) (Figure 8-2)
1. Common in horses
2. Ulcer or stromal abscess
3. *Aspergillus* and *Fusarium* spp.
4. Management
 a. Subpalpebral lavage

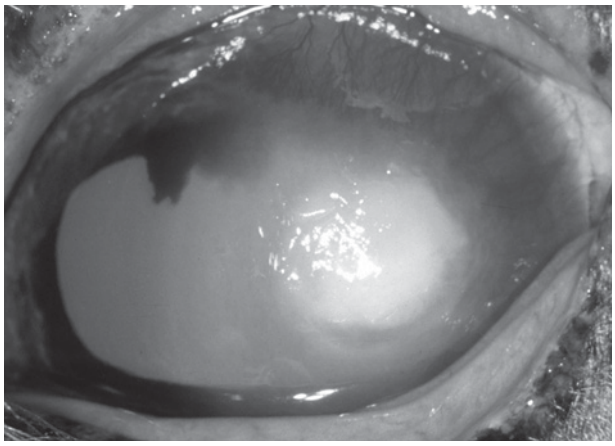


Figure 8-2 Fungal plaque in the left eye of an 11-year-old American Quarter horse gelding being treated medically for fungal keratitis. The yellowish plaque is raised, and blood vessels are approaching the lesion from the temporal aspect. Mild corneal edema can be noted surrounding the plaque. (From Gilger BC. *Equine Ophthalmology*. St Louis, 2006, Saunders.)

 b. Antifungal preparations
 (1) Fluconazole, miconazole, silver sulfadiazine, natamycin
 (2) Miconazole: Intravenous (IV) preparation
 c. Topical atropine 1% drops aiming to dilate the pupil
 d. Systemic nonsteroidal antiinflammatory drugs (NSAIDs) are given to help suppress the uveitis
 e. Surgery may be required

IV. Nonulcerative keratitis

A. Chronic superficial keratitis (pannus)
1. Bilateral disease
2. German shepherd, greyhound, border collie
3. Immune mediated, exposure to ultraviolet (UV) light a trigger
4. Clinical signs
 a. Raised pink swelling of the conjunctiva adjacent to the ventrolateral limbus
 b. Vascularization to produce a granulation tissue appearance that spreads across the cornea
 c. Pigmentation often accompanies the vascularization
 d. Not painful
5. Treatment
 a. Topical cyclosporine
 b. Topical corticosteroids
 c. Subbulbar conjunctiva injections of depo corticosteroid preparations (e.g., Depo-Medrol)
 d. Keratectomy
 e. β-irradiation
 f. Once inflammation is controlled maintenance treatment is necessary:
 (1) Owners need to monitor dogs consistently for recurrence
 (2) Limit UV light exposure, keep indoors, fit with Doggles (www.doggles.com)

B. Eosinophilic keratoconjunctivitis
 1. A unique condition of cats
 2. Corneal lesions are pink and raised with white adherent material
 3. Not painful
 4. Diagnosis
 a. Appearance
 b. Surface scrapings for cytology reveal eosinophils
 5. Treatment
 a. Attempt topical steroids.
 b. Megestrol acetate (Ovaban)

C. Corneal sequestrum (corneal mummification)
 1. A condition unique to cats
 2. Commonest in brachycephalic breeds (e.g., Persians, Himalayans)
 3. Cause: Chronic irritation to the cornea
 4. Appearance: Light brown to black lesion on corneal surface
 5. Management
 a. Leave alone to slough; can cause perforation of cornea
 b. Keratectomy

DISEASES OF THE ANTERIOR UVEA

I. Anatomy of the anterior uvea
 A. Iris
 1. Ciliary zone
 2. Pupillary zone
 3. Iris sphincter muscle
 4. Iris dilator muscle
 B. Ciliary body
 1. Produces aqueous humor
 2. Pars plicata
 3. Pars plana
 4. Zonular fibers of lens attach here

II. Effects of inflammation on the anterior uveal tract
 A. Increased vascular permeability
 B. Breakdown of blood-aqueous barrier
 C. Clinical signs
 1. Hypotony: Decreased production of aqueous humor
 2. Flare: Protein in the anterior chamber
 3. Cell: Inflammatory cells in the anterior chamber
 4. Hypopyon: White cells (pus) in the anterior chamber
 5. Hyphema: Blood in the anterior chamber
 6. Keratic precipitates: Aggregates of cells and inflammatory debris that stick to the corneal endothelium
 7. Miosis: Prostaglandin F-induced ciliary muscle spasm
 8. Cataracts
 9. Posterior synechia: Iris adhered to the anterior lens capsule
 10. Preiridal fibrovascular membrane: Fibrovascular membrane on the surface of the iris
 11. Iris bombe: A 360-degree circumferential posterior synechia that results in pupillary block glaucoma
 12. Lens luxation
 13. Secondary glaucoma

III. Treatment of uveitis
 A. Topical steroids or topical nonsteroidal ophthalmic solutions
 B. Topical atropine to relieve ciliary spasm and miosis
 C. Systemic steroids or systemic NSAIDs
 D. Identify and treat underlying cause
 E. Topical treatment treats only the *anterior* uvea

IV. Infectious diseases that cause anterior uveitis in the dog
 A. Tick-borne disease
 1. *Rickettsia rickettsii*
 2. *Ehrlichia canis*
 3. *Borrelia burgdorferi*
 B. Fungal disease
 1. Blastomycosis
 2. Cryptococcosis
 3. Coccidiomycosis
 4. Histoplasmosis
 C. Bacterial disease
 1. Bacteremia or sepsis
 2. Leptosporosis
 3. Brucellosis
 D. Protozoal
 1. Toxoplasmosis
 2. Leishmaniasis
 E. Viral
 1. Infectious canine hepatitis due to canine adenovirus type-1
 2. Distemper

V. Noninfectious causes of anterior uveitis in the dog
 A. Immune mediated
 1. Lens-induced uveitis
 2. Immune-mediated thrombocytopenia
 3. Uveodermatologic syndrome
 a. Affects pigmented areas of both the eyes and skin
 b. Immune-mediated disorder whereby melanocytes are targeted by cytotoxic T-lymphocytes
 c. Predisposition exists in the Akita, Samoyed, Siberian husky, and Shetland sheepdog
 B. Corneal ulceration
 C. Neoplastic
 1. Primary Intraocular tumors
 a. Uveal melanoma: Most common primary intraocular tumor in dogs
 b. Ciliary body neoplasia
 2. Secondary intraocular tumors: Lymphosarcoma most common
 3. Trauma

VI. Agents associated with feline uveitis
 A. Viral
 1. Feline leukemia virus (FeLV)
 2. Feline immunodeficiency virus (FIV)
 3. Feline infectious peritonitis (FIP)
 B. Protozoal toxoplasmosis
 C. Fungal: Same agents as dogs

VII. Uveitis in the horse: Equine recurrent uveitis (ERU), "moonblindness"
 A. Possible causes
 1. Leptospirosis

2. Onchocerca cervicalis
3. Trauma

B. Bacterial sepsis especially in neonates

GLAUCOMA

I. Pathology
 A. Impairment of the aqueous humor outflow system
 B. Elevation of pressure within the eye
 C. Damages the axoplasmic flow in the optic nerve head resulting in retinal degeneration and a loss of vision
 D. Glaucoma is a leading cause of blindness in the middle-aged dog

II. Anatomy and physiology
 A. Production of aqueous humor
 1. Nonpigmented ciliary body epithelium
 2. Energy-dependent ionic transport, energy-independent hydrostatic and colloid osmotic gradients
 3. An important enzyme in the active secretory (energy-dependent) process is carbonic anhydrase
 B. Normal outflow of aqueous humor
 1. Corneoscleral outflow (conventional outflow, 85% in dogs, 97% in cats). Aqueous passes into the iridocorneal angle, between the fibers of the pectinate ligament through the trabecular meshwork, into the angular aqueous plexus, scleral venous plexus, and ultimately into systemic vascular circulation through the vortex veins and episcleral veins
 2. Uveoscleral outflow (nonconventional, 15% in dogs, 3% in cats). Aqueous humor passes through the trabecular meshwork and passes into the iris stroma or between the ciliary muscle fibers to reach the supraciliary and suprachoroidal spaces where it is absorbed by the vessels of the iris, ciliary body, and choroid

III. Classification of glaucoma
 A. Primary glaucoma
 1. Common in dogs
 2. Abnormal formation of the iridocorneal angle (goniodysgenesis)
 B. Secondary glaucoma: Any disease process can interfere with aqueous outflow and result in secondary glaucoma
 1. Primary lens luxation
 2. Iridocyclitis
 3. Intumescent cataract
 4. Trauma
 5. Hyphema
 6. Retinal detachment (chronic)
 7. Neoplasia
 8. Ocular melanosis

IV. Clinical signs of glaucoma
 A. Acute glaucoma with grossly elevated IOP
 1. Severe pain
 2. Episcleral and conjunctival vascular injection
 3. Corneal edema
 4. Pupillary dilation
 5. Loss of vision
 B. Chronic glaucoma
 1. Buphthalmos
 2. Corneal changes
 a. Corneal vascularization
 b. Exposure keratitis
 c. Corneal (Haab's) striae: Gray, linear streaks that represent breaks in Descemet membrane
 3. Scleral thinning
 4. Decreased evidence of pain
 5. Episcleral vascular engorgement
 6. Subluxated or luxated lens
 7. Iris degeneration
 8. Ciliary body degeneration
 9. Cataract
 10. Funduscopic lesions
 a. Cupped optic disc: Posterior bowing of the lamina cribrosa
 b. Retinal degeneration: Thinning of the retina, increased tapetal reflectivity and retinal vascular attenuation
 c. Optic nerve atrophy

V. Treatment of glaucoma
 A. Medical
 1. Osmotic diuretics (mannitol IV 20%, glycerol 50% oral solution)
 a. Action: Dehydrates the vitreous humor and causes a rapid drop in IOP. Water must be withheld for 2 to 3 hours after administration or the osmotic effect is lost
 b. Contraindications: Compromised cardiovascular or renal function, dehydration, pneumonia, cerebrovascular hemorrhage
 c. Side effects: Severe hypovolemia, fulminant pulmonary edema, renal failure
 2. Carbonic anhydrase inhibitors (CAIs) (methazolamide, acetazolamide, dorzolamide hydrochloride 2% topical)
 a. Action: Decreases aqueous humor production by decreasing the formation of bicarbonate ions
 b. Side effects: Hypovolemia, metabolic acidosis and hypokalemia (panting, vomiting, diarrhea, anorexia, behavioral changes, and rarely KCS)
 3. Miotics, applied topically (pilocarpine 2% solution, phospholine iodide). Action: Increase aqueous humor outflow
 4. Sympatholytic drugs (β-blockers) (timolol maleate, betaxolol hydrochloride, levobunolol HCl)
 a. Action: Reduce aqueous production by an unknown mechanism
 b. Contraindications: Hypotension; may influence cardiac function during anesthesia
 5. Adrenergic drugs (sympathomimetics) (dipivefrin hydrochloride, epinephrine bitartrate). Action: Increases aqueous outflow (α-receptors) and decreases aqueous humor production (β-receptors)
 6. Prostaglandin analogues (latanoprost, travaprost, bimatoprost)
 a. Action: Increases uveoscleral outflow and causes miosis
 b. Can cause marked lowering of IOP

B. Surgical Treatment
 1. Procedures to reduce aqueous production: Cyclodestruction
 a. Cyclocryosurgery
 b. Transscleral cyclophotocoagulation (laser ciliary body ablation)
 c. Intravitreal injection of cyclodestructive drug (pharmacologic ablation of ciliary body)
 (1) Gentamicin
 (2) Destroys retina: Use only in blind eyes
 2. Surgical production of alternative drainage pathways: Drainage implant
 3. Removal of the globe (enucleation) or evisceration
 a. Evisceration and intraocular silicone prosthesis
 b. Enucleation with or without orbital prosthesis

DISORDERS OF THE LENS

I. Anatomy
 A. Capsule
 B. Cortex
 C. Nucleus
 D. Lens sutures
 E. Zonular fibers
II. Lens aging (nuclear sclerosis)
 A. Lens fibers produced throughout life
 B. Central portions become compressed
 C. Hardening (sclerosis) of lens nucleus
 D. Can still see the fundus
III. Cataracts: Any opacity within the lens
 A. Classification of cataracts
 1. Age of animal at onset
 a. Congenital: Present at birth
 b. Juvenile: Occurs in young dogs
 c. Senile: A cataract that develops at 6 years of age and older
 2. Stage of maturation
 a. Incipient: The very smallest opacity. Less than 15% of the lens is opaque
 b. Immature: A tapetal reflection is still visible
 c. Mature: A solid opacity of the lens and absence of a tapetal reflection. (Figure 8-3)
 d. Intumescent: The lens has imbibed water and is "swollen"
 e. Hypermature: Liquefaction of lens cortex begins and the cortex begins to clear
 f. Morgagnian: Liquefaction of the cortex leaving a nuclear remnant that sinks
 3. Location within the lens
 a. Capsular: Opacity confined to the lens capsule
 b. Subcapsular: Most of opacity involves cortex directly beneath lens capsule
 c. Cortical: Opacity of the lens cortex (may be anterior or posterior cortical)
 d. Nuclear: Opacity primarily in center of the lens (nucleus)
 e. Equatorial: Opacity is primarily in the area of the lens equator
 f. Polar and axial: Within the pupillary axis. Usually a focal, central opacity

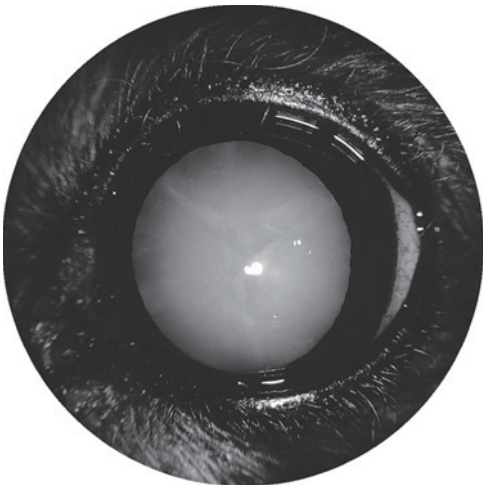


Figure 8-3 Mature cataract. (From Dziezyc J, Millichamp NJ. *Color Atlas of Canine and Feline Ophthalmology.* St Louis, 2005, Saunders.)

 4. Cause
 a. Heritable or genetic: One of the most common causes of cataracts in dogs
 b. Metabolic: Diabetes mellitus
 (1) Hyperglycemia overwhelms normal metabolic pathways in lens: Hexokinase enzyme saturated so aldose reductase enzyme shunts sugars to sorbitol pathway
 (2) Production of nonsoluble sugar alcohol (sorbitol) creates osmotic gradient with influx of fluid into lens
 (3) Disruption of lens fiber membranes leads to protein precipitation and cataract formation
 c. Associated with other ocular abnormalities
 (1) Ocular malformations
 (2) Intraocular disease such as
 (a) Secondary to uveitis
 (b) Glaucoma
 (c) Lens luxation
 (d) Secondary to retinal degeneration
 (e) Senile
 (f) Traumatic: Perforating injury to the cornea and lens (i.e., cat claw)
 5. Others
 a. Nutritional: Canine and feline milk replacers (arginine, tryptophan deficiency)
 b. Electric shock: Anterior subcapsular (puppy that bites an electric cord)
 c. Radiation: Causes ↓ epithelial cell mitosis—young animals more susceptible
 d. Toxic: Disophenol for hookworms
 B. Treatment (cataract surgery)
IV. Abnormalities of the zonular fibers (lens displacement)
 A. Degree of dislocation
 1. Subluxation: Lens remains in the patellar fossa behind the iris
 2. Luxation
 a. Complete displacement of the lens from the patellar fossa

b. Anterior luxation predisposes to glaucoma due to pupillary blockade by the lens and accompanying vitreous

B. Direction of dislocation
1. Anterior
a. Lens anterior to the plane of the iris (in the anterior chamber)
b. Lens usually touching the axial cornea: May cause corneal edema
2. Posterior: Lens in the vitreous cavity

C. Cause
1. Primary luxation
a. Degeneration of lens zonular fibers
b. Breeds predisposed: Terriers
c. Usually anterior luxation
2. Secondary to ocular disease
a. Iridocyclitis (inflammatory zonulysis), especially in cats
b. Chronic glaucoma or buphthalmos
c. Cataracts

D. Treatment: Intracapsular lens extraction

DISEASES OF THE VITREOUS AND FUNDUS

I. Vitreous
A. Anatomy and physiology
1. Vitreous occupies ¾ of the volume of the eye
2. Composition: 98% water
3. Collagen fibrils as skeleton for gel

B. Pathology or diseases of the vitreous
1. Asteroid hyalosis
a. Punctate, calcium-lipid complex
b. Commonly seen in geriatric animals
c. No treatment necessary
2. Synchysis scintillans (liquified vitreous): Cholesterol deposits suspended in a liquefied vitreous (vitreous syneresis)
3. Vitreous hemorrhage
a. Serious event
b. Possible causes: Coagulopathy, retinal detachment, infectious disease, hypertensive retinopathy, trauma, and metastatic or primary neoplasia should be considered
4. Vitritis: Occurs secondary to inflammation of surrounding (pars plana, retina, uvea) ocular tissues

II. Fundus
A. Anatomy
1. Outermost layer = sclera
2. Middle layer = choroid, part of uveal tract, very vascular, special reflective layer = tapetum
3. Innermost layer = retina composed of retinal pigment epithelium and neurosensory retina

B. Congenital anomalies
1. Collie eye anomaly
a. Choroidal hypoplasia lateral to the optic disc
b. Coloboma: "Pits" in the wall of the eye
c. Retinal detachment
d. Intraocular hemorrhage
e. Tortuosity of retinal vasculature
2. Retinal dysplasia (RD)
a. Abnormal development of the retina
b. Vary in severity from lesions that have no effect on vision to blindness
c. Three categories of RD
(1) Multifocal RD
(2) Geographic RD
(3) Total RD
(a) In the Labrador retriever and Samoyed, RD is associated with skeletal dysplasia and the syndrome is called *oculoskeletal dysplasia*
(b) The skeletal abnormalities result in dogs with shortened legs with joint deformities. Oculoskeletal dysplasia in the two breeds is dominant with incomplete penetrance

C. Acquired inherited abnormalities: Progressive retinal atrophy (PRA) are bilateral and progressive, leading to eventual blindness
1. Rod-cone dysplasia (rcd): Animals are typically blind by between 1 and 3 years of age
2. Rod-cone degeneration: Onset is at 2 to 4 years of age, and blindness occurs sometime later
3. Diagnosis: Electroretinogram (ERG)

D. Acquired noninherited abnormalities
1. Sudden acquired retinal degeneration (SARDs)
a. Signalment: Overweight, middle-aged female dogs, usually smaller breeds
b. History: Sudden onset of vision loss (hours to days)
c. Clinical signs: Sudden onset of blindness, absent or depressed pupillary light reflexes (PLRs). The retina initially appears normal. After several days to weeks, the retina will degenerate, resulting in tapetal hyperreflectivity, vascular attenuation, and a pale optic nerve
d. Diagnosis: Extinguished ERG. This disease affects only the rods and cones of the retina
e. Treatment: None
2. Feline central retinal degeneration (FCRD)
a. Dietary taurine deficiency (historically seen in cats fed food formulated for dogs)
b. Lesions are bilaterally symmetrical
c. They start as elliptical lesions dorsal and temporal to the optic papilla (involving area centralis) and may progress to horizontally linear hyperreflective bands above the papilla and even total degeneration of the tapetal fundus
3. Retinitis-chorioretinitis
a. Active: Dull gray area with indistinct margins between normal and affected retina
b. Inactive: Hyperreflectivity of the tapetal fundus; hyperpigmentation of the tapetal fundus (usually focal and may be in the center of a hyperreflective area)
c. Causes: Mycoses (blastomycosis, histoplasmosis, cryptococcosis, coccidiomycosis; bacterial-septicemia; viral-distemper; toxoplasmosis; hypertension; neoplasia-lymphoma; parasitic migration; FIP,

FeLV-lymphoma, FIV, toxoplasmosis in cats, *Streptococcus equi* in horses, thromboembolic meningoencephalitis (TEME), bluetongue, hog cholera, scrapie in food animals

4. Retinal hemorrhage
 a. Thrombocytopenia or thrombocytopathy
 b. Coagulopathy
 c. Vasculitis
 d. Hypertension
 e. Anemic retinopathy
 f. Hyperviscosity syndrome
 g. Radiation-induced
 h. Metastatic neoplasia: Hemangiosarcoma most common.
 i. Senile
5. Retinal detachment or separation
 a. Separation of the neural retina from the retinal pigment epithelium (RPE)
 b. Causes: Inflammatory choroiditis with subretinal exudates, infectious diseases such as mycoses, trauma, congenital (collie eye, dysplasia), immune-mediated, hyperviscosity, hypertension, neoplastic, idiopathic
 c. Treatment
 (1) Treat underlying cause
 (2) Symptomatic treatment for noninfectious disease
6. Equine peripapillary retinopathy (butterfly lesions).
 a. Postinflammatory scars resulting in depigmentation around the optic disc
 b. Some cases may be manifestations of equine recurrent uveitis

DISEASES OF THE OPTIC NERVE

I. Optic nerve hypoplasia: Congenital malformation of the optic nerve
II. Papilledema
 A. Edema of the optic papilla
 B. Causes include increased intracranial pressure (hydrocephalus), neoplasia of the optic nerve, orbital space–occupying masses (abscesses, neoplasms, hemorrhage), neoplasia resulting in compression of the optic nerve fibers, vitamin A deficiency in steers
III. Optic neuritis or papillitis
 A. Animal presents with no PLRs and blindness of the affected eye(s)
 B. Causes include trauma, orbital abscess-neoplasia, metastatic neoplasia, granulomatous meningoencephalitis (reticulosis) or infectious causes (distemper, blastomycosis, cryptococcus, toxoplasmosis, FIP), idiopathic
IV. Optic atrophy: Usually the result of postinflammatory disease, glaucoma, trauma or proptosis, postpapilledema, or massive blood loss or cranial trauma in the horse
V. Coloboma: Pits or excavations of the optic disc or peripapillary region caused by incomplete closure of the embryonic fissure

NEURO-OPHTHALMOLOGY

I. Cranial nerves (CN) with ophthalmic implications
 A. CN II optic: Carries the axons for vision and the PLR
 B. CN III oculomotor
 1. Motor to the dorsal, medial, and ventral rectus muscles and the ventral oblique muscle
 2. Motor to the levator palpebrae superioris
 3. Parasympathetic innervation to the pupillary and ciliary constrictor muscles
 C. CN IV trochlear: Motor to the dorsal oblique muscle
 D. CN V trigeminal
 1. Ophthalmic branch: Corneal and conjunctival sensation and skin sensation of the medial region of the eyelids
 2. Maxillary branch: Skin sensation of the lateral region of the eyelids
 E. CN VI abducens
 1. Motor to the lateral rectus muscle and retractor bulbi muscles (not present in primates and birds)
 2. Sympathetic innervation to the muscles of the cat's third eyelid
 F. CN VII facial
 1. Motor to the orbicularis oculi muscle (closes the eyelids)
 2. Parasympathetic innervation to the lacrimal glands
 G. CN VIII vestibulocochlear
 1. Sensory information for hearing, balance, and ocular motility
 2. Position with regard to gravity
 3. Detection of linear or rotational stimuli of the head
 4. Postural and ocular motility reflexes generated by these positional changes
II. The visual pathway
 A. Photon of light
 B. Hits retina
 C. Relayed along optic nerve
 D. Crosses at optic chiasm (about 65% in the cat; 75% in the dog; up to 90% in cows, horses, sheep and pigs; and 100% in most fish, birds, and reptiles)
 E. Optic tracts
 F. Lateral geniculate nucleus: Approximately 20% of the fibers diverge from the optic tracts before reaching the lateral geniculate nucleus and are involved in generating the pupillary light reflex (see section below). Therefore the pupillary light reflex is *not* a test for vision
 G. Optic radiations
 H. Visual cortex of the occipital lobes of the cerebrum
III. Ocular reflexes
 A. PLRs (II and III): In simplistic terms, PLR or visual pathway lesions will have the following characteristics:
 1. Afferent arm: Vision loss and direct PLR deficit present

2. Efferent arm: No vision loss; direct or consensual deficit present
3. Cortical: Vision loss, no PLR deficit

B. The menace response (II and VII)
1. Make a menacing gesture with your hand toward the eye while covering the contralateral eye. The animal should blink in response to the stimulus
2. This is a learned response, not a reflex, and is frequently absent in young animals

C. The dazzle reflex (II and VII). Technique: Direct a high intensity light into the animal's eye. This reflex does not mean that the animal "sees," but it does mean there is some function to the retina, optic nerve, and visual tract

D. Palpebral reflex (V and VII). Technique: Touch the animal at the medial canthus and lateral canthus and evaluate for a blink response to the stimulus

E. Corneal reflex (V and VII). Technique: Before applying topical anesthetic to the cornea, use a few wisps from a cotton ball or cotton swab (or an aesthesiometer) to touch the surface of the cornea and monitor for a blink response

F. Vestibulo-ocular reflex (VIII and III, IV, and VI). Technique: Move the head back and forth and observe that the eyes move equally in the opposite direction of the head movement

IV. Horner syndrome

A. Definition: Loss of sympathetic innervation to the eye

B. Anatomy of the sympathetic innervation to the eye: three components
1. Central neuron: From hypothalamus to T1-T3 of spinal cord
2. Preganglionic neuron: Brachial plexus, anterior mediastinum, the neck along with the jugular vein and carotid artery, ending just caudomedial to the tympanic bullae
3. Postganglionic neuron: From the cranial cervical ganglion, through the middle ear and cavernous sinus, to the orbit to innervate the iris dilator muscle

C. Signs of Horner syndrome (Figure 8-4)
1. Miosis: Loss of dilator muscle function
2. Ptosis: Mueller muscle paralysis
3. Enophthalmos: Loss of tone from muscularis orbitalis
4. Protrusion of nictitans: From loss of smooth muscle tone to nictitans and enophthalmos
5. Increased sweating over affected side of face in horses, decreased sweating in cattle (the ipsilateral nostril will be dry)

D. Causes of Horner syndrome
1. Central (usually associated with other signs)
 a. Injury (spinal)
 b. Neoplasia
 c. Embolic infarct, disk compression
2. Preganglionic
 a. Brachial plexus avulsion
 b. Anterior mediastinal lymphosarcoma (cats)
 c. Neck injuries (misplaced injection in horses)
3. Postganglionic
 a. Otitis media or interna (small animals), tumors
 b. Orbital tumors
 c. Guttural pouch disease (horses)
4. Horner syndrome: Often (i.e., in more than 50% of cases) idiopathic in dogs and cats

E. Localization of the lesion
1. Clinical signs: Suggestive
2. Pharmacologic testing
 a. Differentiates preganglionic vs. postganglionic Horner syndrome
 b. 10% phenylephrine ophthalmic solution: To evaluate for denervation hypersensitivity and confirm the presence of Horner syndrome



Figure 8-4 Presenting signs of Horner syndrome (autonomic denervation) include a quadrad of ocular signs in small animals. In this cat with Horner syndrome of the right eye, the classic signs (MEPP) of miosis, enophthalmos, protrusion of the third eyelid, and ptosis are present. (From Dziezyc J, Millichamp NJ. *Color Atlas of Canine and Feline Ophthalmology.* St Louis, 2005, Saunders.)

Supplemental Reading

Gelatt KN. *Veterinary Ophthalmology*, 3rd ed. Baltimore, 1999, Lippincott Williams & Wilkins.

Gilger BC. *Equine Ophthalmology*. St Louis, 2005, Saunders.

Maggs DJ, Miller PE, Ofri R. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed. St Louis, 2007, Saunders.

Peiffer RL, Petersen-Jones SM. *Small Animal Ophthalmology: A Problem-Oriented Approach*, 4th ed. St Louis, 2008, Saunders.

Petersen-Jones SM, Crispin SM. *BSAVA Manual of Small Animal Ophthalmology*, 2nd ed. Gloucester, UK, 2002, BSAVA.

Riis RC. *Small Animal Ophthalmology Secrets*, Philadelphia, 2002, Hanley & Belfus.

9 CHAPTER

Pharmacology

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CARDIOVASCULAR DRUGS

I. Diuretics
 A. Furosemide
 1. Mechanism of action
 a. Blocks reabsorption of chloride in the loop of Henle
 b. Increases urinary excretion of sodium, chloride, calcium, magnesium, and potassium
 c. Mild venodilator, shifting fluid from pulmonary to systemic circulation
 2. Indications
 a. Congestive heart failure (CHF)
 b. Pulmonary edema, pleural effusion, ascites
 c. Oliguric renal failure (increases urine flow)
 d. Hypercalcemia
 3. Side effects: Dehydration, prerenal azotemia, hypokalemia, hypochloremic metabolic acidosis; cats more sensitive to adverse effects
 B. Spironolactone
 1. Mechanism of action: Aldosterone antagonist
 a. Moderate diuretic effect
 b. Acts in distal renal tubule and collecting ducts
 c. Leads to sodium reabsorption, and potassium and hydrogen secretion
 2. Indications
 a. Second-line diuretic for CHF
 b. Ascites due to portal hypertension. Can be used in combination with hydrochlorthiazide
 3. Side effects: Hyperkalemia and gastrointestinal (GI) upset (uncommon)
 C. Thiazide diuretics (e.g., hydrochlorthiazide)
 1. Mechanism of action
 a. Weak diuretic
 b. Blocks sodium and chloride reabsorption in the distal tubule
 c. Increases calcium reabsorption
 d. Decreases potassium and magnesium absorption
 2. Indications: Management of ascites and edema; used in combination with spironolactone
 3. Side effects: Mild hypokalemia, hypomagnesemia, hypochloremic metabolic alkalosis, hyponatremia; contraindicated with hypercalcemia

II. Vasodilators
 A. Angiotensin-converting enzyme (ACE) inhibitors (e.g., enalapril, benazepril).
 1. Metabolized by liver to active drugs (enalaprilat or benazeprilat). Enalaprilat excreted in urine; benazeprilat excreted in urine and bile
 2. Mechanism of action
 a. Blocks ACE (lungs and vascular endothelium). Prevents the conversion of angiotensin I to angiotensin II
 b. An arterial and venous dilator
 (1) Decreases total peripheral and pulmonary vascular resistance
 (2) Decreases systemic blood pressure
 3. Indications
 a. CHF
 (1) Afterload reduction
 (2) Shifts blood from pulmonary to venous circulation
 b. Hypertension
 c. Protein-losing nephropathy
 (1) Decreases glomerular protein loss
 (2) May decrease mesangial cell proliferation and glomerular fibrosis
 4. Side effects and contraindications: GI upset, hypotension, prerenal azotemia, hyperkalemia (uncommon); contraindicated in dehydration
 B. Amlodipine
 1. Calcium channel blocker that is used as a vasodilator, not an antiarrhythmic
 2. Mechanism of action
 a. Greatest effect on vascular smooth muscle. Peripheral arteriolar vasodilator
 b. Little effect on automaticity, conduction velocity of the atrioventricular (AV) or sinoatrial (SA) nodes, or myocardial contractility
 3. Indications: Hypertension
 4. Side effects: Negative inotropic effects, hypotension (reflex tachycardia)
 C. Nitroglycerin
 1. Mechanism of action
 a. Venodilator
 b. Donor of nitric oxide
 c. Reduces preload via pulmonary vein dilation. Shifts blood from pulmonary to venous system.
 2. Indications: CHF. Topical use (ointment or patch)
 3. Side effects: Hypotension, irritation at site of application, tolerance with continued therapy
 D. Hydralazine
 1. Mechanism of action

a. Potent arterial vasodilator
b. Direct action on vascular smooth muscle to decrease contractility by modification of calcium metabolism
c. Decreases systemic vascular resistance
d. Decreases afterload
2. Indications: CHF, severe or refractory hypertension
3. Side effects: Hypotension, reflex tachycardia, GI upset

E. Prazosin
1. Mechanism of action
a. α-1 adrenergic antagonist
b. Balanced vasodilator
c. Reduces preload and afterload
2. Indications: CHF, refractory hypertension
3. Side effects: GI upset, syncope (first-dose effect), development of drug tolerance

III. Antiarrhythmics
A. Class I (e.g., lidocaine, quinidine, procainamide, mexiletine)
1. Shared mechanisms of action
a. Membrane stabilizers
b. Inhibit fast sodium channels
c. Inhibit the rate of spontaneous depolarization
2. Lidocaine
a. Little or no effect on SA or AV nodes or atrial muscle
b. Indications: Drug of choice to treat life-threatening ventricular arrhythmias Not effective orally owing to significant first-pass hepatic metabolism, intravenous (IV) administration only
c. Side effects: Vomiting, central nervous system (CNS) signs (ataxia, depression, nystagmus, seizures; treat with diazepam). Use with caution in patients with hepatic failure; cats more sensitive to CNS side effects (lower doses used)
3. Procainamide
a. Additional mechanisms
(1) Prolongs refractory period in both the atria and ventricles
(2) Decreases myocardial excitability
(3) Anticholinergic effects
b. Indications: Used IV for lidocaine-refractory ventricular arrhythmias
c. Side effects and contraindications: GI upset, do not use with second- or third- degree AV block, drug-induced arrhythmias, may cause hypotension with rapid IV administration; contraindicated in myasthenia gravis
4. Mexiletine
a. Oral analogue of lidocaine
b. Indications: Oral drug of choice for ventricular arrhythmias in dogs
c. Side effects and contraindications: GI upset. Do not use with second- or third- degree AV block
5. Quinidine
a. Prolongs the duration of the action potential and refractory period in both the atria and ventricle. Like procainamide, also has anticholinergic effects
b. Indications
(1) Atrial fibrillation
(a) Direct effect on atrial muscle
(b) Anticholinergic effect prolongs atrial refractory period
(c) Converts atrial fibrillation to normal sinus rhythm in horses
(2) Refractory supraventricular tachycardias
(3) Ventricular arrhythmias
c. Side effects: GI upset, hypotension, worsening of CHF,AV block
d. Contraindications: Digoxin toxicity, myasthenia gravis

B. β blockers (Class II antiarrhythmics)
1. Mechanisms: Adrenergic receptor antagonists
a. Decrease sinus heart rate
b. Increase the refractory period of the AV node
c. Decrease myocardial oxygen demand
d. Decrease cardiac inotropy
2. Propranolol
a. Mechanism: Nonselective β-adrenergic antagonist; both β-1 and β-2 receptor blockade
b. Indications
(1) Supraventricular arrhythmias
(2) Ventricular arrhythmias
(3) Hypertrophic and thyrotoxic heart disease
c. Side effects: Negative inotropic effect, bradycardia, hypotension, decreased hepatic blood flow (decreases clearance of lidocaine), β-2 blockade (hypoglycemia, hepatic receptors; bronchoconstriction, bronchial receptors)
d. Contraindications: Overt heart failure, sinus bradycardia, asthma
3. Atenolol, metoprolol, esmolol
a. Mechanism of action
(1) β-1 adrenergic selective receptor antagonists
(2) Decrease risk of bronchospasm
b. Indications
(1) Supraventricular arrhythmias
(2) Atenolol drug of choice for feline arrhythmias
(3) Hypertrophic and thyrotoxic heart disease
(4) Esmolol used IV only (short half life)
c. Side effects: Negative inotropic effect, hypotension, lethargy, diarrhea
d. Contraindications. Bradyarrhythmias

C. Class III antiarrhythmics
1. Mechanisms: Block potassium channels
a. Prolong the refractory period
b. Increase the duration of the action potential
c. Greatest effects in Purkinje fibers and ventricular muscle
2. Sotalol
a. Combination class II and class III antiarrhythmic

(1) Nonselective β-adrenergic receptor antagonist
(2) Potassium channel blocker
b. Indications: Refractory ventricular arrhythmias; boxer arrhythmias
c. Side effects: Drug-drug interactions, negative inotropy, proarrhythmic, bronchospasm, GI upset
d. Contraindications: Asthma, sinus bradycardia, second- or third-degree heart block
3. Amiodarone
a. Mechanism of action
(1) Structural analogue of thyroid hormone
(2) Inhibits α and β receptors (nonselective, noncompetitive)
(3) Inhibits sodium and calcium channels
(4) Prolongs action potential duration and refractory period
b. Indications. Reserved for refractory ventricular tachycardia
c. Side effects: Many drug interactions, GI upset, neutropenia, hepatotoxicity
d. Contraindications: Second- and third-degree AV block, bradyarrhythmias

D. Calcium channel blockers (class IV antiarrhythmics)
1. Mechanism
a. Block influx of calcium through slow calcium channels during plateau of action potential
b. Slow SA and AV node conduction
c. Decrease vascular smooth-muscle contractility. Systemic and coronary vasodilation
d. Decrease myocardial contractility (negative inotropy)
2. Diltiazem
a. Slows AV conduction velocity and prolongs refractory period (rarely affects SA node conduction)
b. Minimal effect on cardiac contractility
c. Mild peripheral vasodilation
d. Indications
(1) Supraventricular tachyarrhythmias (atrial fibrillation)
(2) Hypertrophic cardiomyopathy (cats)
e. Side effects: Bradycardia (dogs), GI upset (cats), hypotension, arrhythmias
f. Contraindications: Potentiate the negative inotropic and chronotropic effects of β-adrenergic antagonists; severe hypotension, sick sinus syndrome, second- or third-degree AV block
3. Verapamil
a. Pronounced effect on AV node
(1) Increased refractory period
(2) Decreased automaticity and AV conduction
b. Clinically significant negative inotropy
c. Decreased peripheral vascular resistance
d. Indications: Supraventricular tachyarrhythmias
e. Side effects: Increased blood levels of digoxin and theophylline; hypotension (resulting from systemic vasodilation); heart block
f. Contraindications: Use with β-adrenergic antagonists, hypotension, sick sinus syndrome, second- or third-degree heart block

IV. Adrenergic agonists
A. Dobutamine
1. Mechanism of action
a. Synthetic catecholamine
b. Direct β-1 agonist with mild β-2 and α-1 adrenergic effects
(1) Increased myocardial contractility and output
(2) Minimal effects on systemic blood pressure or heart rate
2. Indications: Cardiogenic shock; intended for short-term use (48 to 72 hours)
3. Side effects: β-1 receptor desensitization occurs with prolonged use, ectopic beats, increased heart rate or blood pressure

B. Dopamine
1. Mechanism of action
a. Endogenous catecholamine that acts on α- and β-adrenergic receptors and dopamine receptors
b. Positive inotrope; stimulation of cardiac β-1 receptors
c. Pharmacological effects are dose dependent
(1) Low dose (2 μg/kg/min): Stimulates dopaminergic receptors to increase mesenteric, coronary, and renal blood flow
(2) Moderate dose (5 μg/kg/min): Cardiac β-1 adrenergic stimulation, producing increased cardiac output with minimal effects of peripheral vasculature
(3) High dose (>10 μg/kg/min); Stimulates α-adrenergic receptors producing peripheral vasoconstriction and increased blood pressure
2. Indications: Refractory hypotension; acute renal failure
3. Side effects: Tachycardia, arrhythmias, increased myocardial oxygen demand
4. Contraindications: Pheochromocytoma, ventricular fibrillation, uncorrected tachyarrhythmia

V. Digoxin
A. Mechanism of action
1. Mild positive inotrope. Inhibits Na/K/ATPase pump, promoting Na/Ca exchange and increasing intracellular calcium concentrations
2. Slows rapid ventricular rates; increases parasympathetic tone
3. Neurohormonal modulation. Reduces plasma levels of norepinephrine, aldosterone, renin

B. Indications
1. CHF (decreased contractility): Dilated cardiomyopathy or valvular disease
2. Supraventricular tachycardia (atrial fibrillation)

C. Side effects
1. Digoxin toxicity (narrow therapeutic range). Therapeutic drug monitoring recommended

2. Extracardiac: GI upset, muscle weakness, depression, disorientation
3. Cardiac: Partial or complete heart block, ventricular arrhythmias
4. Many drug interactions

VI. Phosphodiesterase inhibitors
- A. Mechanisms
 1. Positive inotropes or vasodilators
 2. Inhibit phosphodiesterase type III (cardiac-specific phosphodiesterase)
 a. Increased intracellular cAMP
 b. Increased myocardial contractility
 3. Arteriodilation and venodilation (both pulmonary and systemic vasculature)
 4. Potentiate adrenergic signal transduction
 a. Increases myocardial contractility (positive inotrope)
 b. Increases myocardial relaxation
 5. Enhanced cardiac contractility without increased myocardial oxygen consumption
- B. Pimobendan.
 1. Additional mechanisms
 a. Potentiates adrenergic signal transduction (positive inotrope; increases myocardial relaxation)
 b. Enhanced cardiac contractility without increased myocardial oxygen consumption
 2. Indications: CHF, dilated cardiomyopathy or valvular disease
 3. Side effects: Arrhythmias, mild GI upset
- C. Amrinone, milrinone
 1. Indications
 a. CHF (decreased contractility). Dilated cardiomyopathy or valvular disease
 b. Arterial hypertension
 c. Milrinone is 10 to 20 times more potent
 2. Side effects: Arrhythmias, GI upset, thrombocytopenia, hepatotoxicity, fever

PULMONARY DRUGS

I. Methylxanthines (e.g., theophylline, aminophylline [theophylline ethylenediamine salt; 80% theophylline])
- A. Mechanisms of action
 1. Direct smooth muscle relaxation of bronchi and pulmonary vasculature (bronchodilation and vasodilation)
 2. Competitive inhibition of phosphodiesterase: Increases cAMP levels, which increase endogenous epinephrine
 3. Competitive antagonism of adenosine
 4. Interference with calcium mobilization
 5. Other effects
 a. Inhibit histamine release (inhibition of mast cell degranulation) and inflammatory mediator release
 b. Increase mucociliary clearance
 c. Prevent microvascular leakage
 d. Increase strength of respiratory muscles
- B. Indications: Bronchospasm. Extended released formulations available
- C. Side effects: CNS signs (excitement, seizures, restlessness), GI upset, polyuria, polydipsia. Narrow therapeutic range
- D. Contraindications: Cardiac arrhythmias, hypertension, gastric ulcers, renal or hepatic disease, hyperthyroidism

II. β-2 adrenergic agonists
- A. Mechanisms
 1. Relaxation of bronchial smooth muscle
 a. Activation of β-2 adrenergic receptors
 b. Increased cAMP via activation of adenyl cyclase
 (1) Activation of protein kinase A (bronchodilation)
 (2) Inhibition of inflammatory cell mediator release
 2. Stimulate secretion of mucus
 3. Enhance mucociliary clearance
- B. Terbutaline, albuterol
 1. Selective β-2 adrenergic receptor agonists
 2. Indications: Bronchospasm. Albuterol available as inhaler
 3. Side effects: Tremors, tachycardia, CNS excitement (secondary to nonspecific β-1 receptor activation at high doses)
 4. Contraindications: Cardiac arrhythmias, hypertension, seizures, hyperthyroidism. Use with caution
- C. Epinephrine
 1. Nonselective β- adrenergic agonists. Stimulates β-1, β-2, and α-adrenergic receptors
 2. Indications
 a. Allergic reactions (insect bites, urticaria)
 b. Acute severe bronchospasm
 3. Side effects: Tachycardia, vasoconstriction, hypertension (result of β-1 and β- adrenergic receptor activation)

III. Opioid cough suppressants
- A. Butorphanol
 1. Mechanism of action
 a. Synthetic opioid
 b. Mixed agonist-antagonist: κ-receptor agonist, weak μ-receptor antagonist
 c. Suppresses afferent input into coughing center (medulla)
 2. Indications: Antitussive in dogs with minimal to no sedation; mild analgesia
 3. Side effects: Sedation (higher doses); significant hepatic first-pass effect (requires higher oral dosing). Minimal cardiac and respiratory depression
- B. Hydrocodone
 1. Mechanism of action
 a. Opioid agonist
 b. Suppression of afferent input into coughing center (medulla)
 c. Drying effect on respiratory mucosa
 2. Indications: Antitussive in dogs
 3. Side effects: Sedation, respiratory and cardiac depression, constipation

IV. Inhaled glucocorticoids: Fluticasone
- A. Mechanism of action
 1. Trifluorinated glucocorticoid

2. Potent antiinflammatory activity
3. High topical potency
4. Low systemic bioavailability
5. Bronchodilation

B. Indications: Allergic airway disease and feline asthma

C. Side effects: Suppression of hypothalamic-pituitary-adrenal (HPA) axis; contraindicated with acute bronchospasm

GASTROINTESTINAL (GI) DRUGS

I. Histamine type 2 (H_2) blockers (e.g, cimetidine, ranitidine, famotidine)
 A. Mechanism: Inhibit H_2 receptors in gastric parietal cells, blocking HCl secretion. Ranitidine may also have some prokinetic activity
 B. Indications: Reflux esophagitis, gastric ulcers, mast cell tumors, vomiting from liver or renal disease
 C. Side effects and contraindications: Cimetidine is a P450 inhibitor and decreases clearance of many drugs, leading to drug interactions

II. Pump blockers (e.g., omeprazole)
 A. Mechanisms: Proton pump inhibitor; inhibits NH+/K+ ATPase and inhibits HCl secretion in gastric parietal cells
 B. Indications: Reflux esophagitis, severe gastric ulcers, mast cell tumors, gastrinoma
 C. Side effects and contraindications: Omeprazole is a P450 inhibitor and decreases the clearance of some drugs in people

III. Gastroprotectants (e.g., sucralfate, misoprostol)
 A. Mechanisms
 1. Sucralfate is an aluminum-containing disaccharide that forms a gel and binds to ulcer beds
 2. Misoprostol is a prostaglandin E_1 (PGE_1) analog that promotes healing of ulcers caused by nonsteroidal antiinflammatory drugs (NSAIDs)
 B. Indications
 1. Sucralfate: Gastric or esophageal ulceration
 2. Misoprostol: Prevention and treatment of NSAID-induced gastric and duodenal ulcers
 C. Side effects and contraindications
 1. Sucralfate binds to many drugs and decreases their bioavailability, particularly doxycycline and fluoroquinolones. Should be given at least 2 hours *after* other drugs
 2. Misoprostol can cause cramping and diarrhea; contraindicated in pregnancy

IV. Prokinetic agents (e.g., metoclopramide, cisapride)
 A. Mechanisms
 1. Metoclopramide increases gastric and intestinal motility by sensitizing the GI tract to acetylcholine
 2. Cisapride has a similar mechanism of action, but also improves colonic motility
 3. Metoclopramide (but not cisapride) is also a central antiemetic via inhibition of dopaminergic receptors
 B. Indications
 1. Gastric atony, ileus, megaesophagus (may reduce reflux)
 2. Metoclopramide only: Nausea and vomiting without obstruction
 3. Cisapride only: Constipation and megacolon
 C. Side effects and contraindications
 1. Prokinetic agents are contraindicated in cases of GI obstruction
 2. Metoclopramide at high doses can cause tremor. Because of renal elimination, the dose should be reduced in patients with renal insufficiency
 3. Cisapride has several drug interactions (e.g. with azole antifungals)

V. Antiemetics: Phenothiazines (e.g., chlorpromazine, prochlorperazine)
 A. Mechanisms: Inhibit dopaminergic, cholinergic, and histaminergic receptors to reduce input to the emetic center
 B. Indications: Refractory vomiting of defined cause. Use with fluid support
 C. Side effects and contraindications: Hypotension, ileus; masks obstruction. Contraindicated in horses because of ataxia and excitation

VI. Antiemetics: Serotonergic antagonists (e.g., ondansetron, dolasteron)
 A. Mechanisms: 5-Hydroxytryptamine type 3 (5-HT3) antagonist; blocks input to emetic center
 B. Indications
 1. Chemotherapy-induced nausea
 2. Intractable vomiting and nausea unresponsive to less expensive drugs
 C. Side effects and contraindications: Potential to cause CNS signs in collies and other herding dogs with *p*-glycoprotein defect (*p*-glycoprotein substrate)

VII. Antiemetics: Antihistamines
 A. Examples: Diphenhydramine (e.g., Benadryl), dimenhydrinate (e.g., Dramamine)
 B. Mechanisms
 1. H_1 receptor antagonists; block input to emetic center
 2. Also have some anticholinergic effects
 C. Indications
 1. Diphenhydramine: Adjunct to prevent chemotherapy-induced nausea
 2. Dimenhydrinate: Motion sickness
 D. Side effects and contraindications: Sedation (dogs), excitation or sedation (cats); contraindicated in glaucoma due to anticholinergic effects

VIII. Antidiarrheals: Adsorbents
 A. Examples: Bismuth subsalicylate (Pepto-Bismol), kaolin and pectin (Kaopectate)
 B. Mechanisms
 1. Bismuth has antiendotoxin and weak antibacterial properties; salicylate may reduce secretion in secretory diarrheas
 2. Kaolin and pectin are thought to act as adsorbents, with minimal efficacy data
 C. Indications
 1. Acute diarrhea in dogs, foals, baby pigs
 2. Bismuth subsalicylate only: Part of therapy for *Helicobacter*-associated gastritis
 D. Side effects and contraindications
 1. May adsorb and impair absorption of other drugs

2. Pepto-Bismol and newer formulations of Kaopectate contain salicylate, which should be used with caution in cats
3. Bismuth subsalicylate will turn stools greenish black

IX. Antidiarrheals: Opioids (e.g.,diphenoxylate [Lomotil; also contains atropine], loperamide [Immodium])
- A. Mechanism
 1. Synthetic opiate agonists, without CNS side effects
 2. Increase segmental contractions of gut, but decrease "downstream" movement
 3. Increase time available for water resorption and decrease frequency of bowel movements
 4. Atropine in Lomotil contributes to decreased motility but primarily is included to decrease abuse potential
- B. Indications: Short-term (i.e., less than 48 hours) therapy of acute diarrheas in dogs
- C. Side effects: Constipation. Contraindicated for infectious diarrheas (*Salmonella,* parvovirus). Opiates not recommended in cats because of excitation

X. Antidiarrheals: Anticholinergics (e.g., aminopentamide [Centrine], propantheline [Pro-Banthine])
- A. Mechanisms: Anticholinergic, labeled for use as an antispasmodic antidiarrheal
- B. Indications: Not recommended for use in dogs and cats
- C. Side effects and contraindications: Can mask signs of disease progression; ileus

XI. Antiinflammatories
- A. Salicylate derivatives (e.g., sulfasalazine, olsalazine)
 1. Mechanism
 a. 5-aminosalicylic acid (5-ASA) linked to a sulfa moiety (sulfasalazine) or another 5-ASA molecule (olsalazine)
 b. Cleaved by colonic bacteria to release antiinflammatory 5-ASA
 2. Indications: Chronic inflammatory colitis in dogs; uncommonly used in cats
 3. Side effects. Keratoconjunctivitis sicca (KCS; dry eye) in about 15% of dogs given sulfasalazine
- B. Glucocorticoids (e.g., prednisone-prednisolone, dexamethasone, budesonide)
 1. Indications: Histologic evidence of GI inflammatory infiltrates or lymphangiectasia
 2. Budesonide: High first-pass effect, low systemic blood levels. May cause fewer systemic side effects
- C. Azathioprine (Imuran)
 1. Mechanism
 a. Purine analogue that inhibits ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) synthesis
 b. Antiinflammatory and immunosuppressive
 2. Indications: Lymphangiectasia, refractory or severe inflammatory bowel disease
 3. Side effects of azathioprine: Neutropenia, thrombocytopenia, pancreatitis, hepatopathy (increased alanine aminotransferase [ALT]). Not recommended for use in cats because of impaired detoxification of azathioprine
- D. Cyclosporine
 1. Mechanism
 a. Inhibitor of T-cell function
 b. Immunosuppressive agent; may deplete T cells
 2. Same indications as for azathioprine
 3. Side effects of cyclosporine: Vomiting, inappetence, gingival lesions, alopecia, secondary fungal infections

XII. Treatment of constipation
- A. Lubricants
 1. Petrolatum (e.g., Laxatone)
 a. Daily therapy for hairballs
 b. May be sufficient for mild constipation in cats
 2. Mineral oil: May impair water resorption in colon; risk of aspiration
- B. Bulking agents
 1. Psyllium (Metamucil)
 2. Hemicellulose-containing seed extract
 3. Insoluble fiber source; adsorbs water and swells, increasing fecal bulk
- C. Osmotics: Lactulose
 1. Osmotic laxative; disaccharide of galactose and fructose
 2. Nonabsorbable disaccharide which is metabolized by colonic bacteria to release volatile fatty acids. These osmotically active acids draw water into the colon and hydrate colon contents
- D. Surfactants: Docusate sodium (DSS)
 1. Stool softener; detergent surfactant
 2. Emulsifies, hydrates, and softens fecal contents permeability
 3. DSS is a mucosal irritant; may increase the absorption of drugs such as digoxin and quinidine
- E. Motility enhancers
 1. Cisapride: Prokinetic agent related to metoclopramide, but cisapride also acts on smooth muscle of colon
 2. Bisacodyl (Dulcolax): Increases water permeability of mucosal cells (may alter tight junctions); increases electrolyte flux to lumen, probably by inhibiting Na^+/K^+ ATPase; may increase secretion and motility

DRUGS FOR HEPATIC DISEASE

I. Hepatoprotectants
- A. Ursodiol
 1. Mechanisms: Increases bile flow (choleretic); may reduce hepatotoxic effects of bile salts
 2. Indications: Inflammatory and cholestatic liver diseases in dogs and cats
 3. Side effects and contraindications: Contraindicated with biliary obstruction
- B. S-adenosylmethionine
 1. Mechanisms: Glutathione precursor; may have other hepatoprotective effects
 2. Indications
 a. Hepatic inflammation and necrosis in dogs and cats
 b. Acetaminophen toxicosis

3. Side effects and contraindications: Possible adverse interaction with tricyclic antidepressants

C. Silymarin (milk thistle extract)
1. Mechanisms: May have antioxidant properties; may have antiinflammatory properties via inhibition of 5-lipoxygenase
2. Indications: Empirical treatment of hepatic inflammation and necrosis in dogs and cats
3. Side effects and contraindications: Formulations may vary in content and potency (over-the-counter [OTC] nutraceutical)

II. Drugs for hepatic encephalopathy
A. Lactulose
1. Mechanism: Converted to osmotically active acids in colon; traps ammonia and reduces its absorption. Acts as osmotic cathartic
2. Indications: Hepatic encephalopathy; also constipation
3. Side effects and contraindications: Dose-dependent diarrhea

B. Neomycin
1. Mechanisms: Inhibits ammonia generation in colon; poorly absorbed aminoglycoside used orally
2. Indications: Hepatic encephalopathy
3. Side effects and contraindications: Bitter taste

C. Metronidazole
1. Mechanisms: Kills ammonia-producing anaerobes in colon
2. Indications: Hepatic encephalopathy; also used for anaerobic infections
3. Side effects and contraindications: Cerebellovestibular neurologic signs with overdose; anorexia, GI upset

III. Antifibrotics: Colchicine
A. Mechanisms
1. Microtubule inhibitor
2. Inhibits procollagen secretion

B. Indications: Used empirically for fibrotic liver disease with or without ascites

C. Side effects and contraindications: GI upset (dose dependent); peripheral neuropathy, myopathy, and bone marrow suppression less common

IV. Decoppering agents
A. D-penicillamine
1. Mechanisms
a. Chelates plasma copper to allow urinary excretion
b. May also inhibit hepatic fibrosis
2. Indications. Biopsy diagnosis of copper-associated hepatopathy
3. Side effects: GI upset (common); contraindicated in pregnancy

B. Zinc
1. Mechanisms
a. Decreases copper absorption
b. Induces metallothionein synthesis by enterocytes, which binds intestinal copper and prevents absorption
c. May also have antifibrotic effects
2. Indications
a. Used empirically for hepatopathies associated with mild to moderate copper accumulation
b. Used empirically for mild to moderate fibrosis
3. Side effects and contraindications: GI upset; high plasma zinc levels lead to hemolysis

DRUGS FOR ENDOCRINE DISEASE

I. Thyroid disease
A. Methimazole
1. Mechanism: Inhibits thyroid peroxidase and thyroid hormone synthesis
2. Indications: Medical management of hyperthyroidism
3. Side effects and contraindications: GI upset (dose dependent); idiosyncratic reactions (facial excoriation, thrombocytopenia, neutropenia, hepatopathy); treatment can unmask underlying renal disease

B. Radioiodine
1. Mechanisms: Actively captured by thyroid glands; destroys active thyroid tissue via local β irradiation
2. Indications: Hyperthyroidism (generally curative)
3. Side effects and contraindications: Requires short quarantine; treatment can unmask underlying renal disease

C. L-thyroxine
1. Mechanisms: Physiologic replacement of T4
2. Indications: Hypothyroidism
3. Side effects and contraindications: Excess dose can lead to tremor, tachycardia, weight loss. Bioavailability varies; monitor with post-pill (4 to 6 hours) thyroid hormone concentrations

II. Drugs for adrenal disease
A. Hyperadrenocorticism
1. Mitotane
a. Mechanisms
(1) Toxic to zona fasciculata and zona reticularis layers of the adrenal glands
(2) Decreases glucocorticoid secretion
b. Indications
(1) Pituitary dependent hyperadrenocorticism in dogs
(2) At high doses, treatment of inoperable glucocorticoid-secreting adrenal tumors
c. Side effects and contraindications: Direct GI upset; hypocortisolemia with resulting lethargy and GI upset. Generally spares aldosterone-secreting zona glomerulosa unless very high doses used
2. Trilostane
a. Mechanisms
(1) Inhibits adrenal enzyme 3-beta-hydroxysteroid dehydrogenase
(2) Decreases cortisol and aldosterone secretion
b. Indications: Pituitary dependent hyperadrenocorticism in dogs

c. Side effects and contraindications: Hypocortisolemia with resulting lethargy and GI upset; hyponatremia and hyperkalemia

B. Hypoadrenocorticism
1. Mineralocorticoid supplementation
a. Desoxycorticosterone pivalate (DOCP)
(1) Mechanism: Long-acting injectable mineralocorticoid given about every 25 to 28 days
(2) Indications: Hypoadrenocorticism with hyponatremia or hyperkalemia
(3) Side effects and contraindications
(a) Dose and dosing interval must be adjusted based on serum electrolytes
(b) No glucocorticoid activity; requires adjunct use of glucocorticoids for treatment of hypoadrenocorticism
b. Fludrocortisone
(1) Short-acting oral mineralocorticoid
(2) Given daily
(3) Indicated as for DOCP
(4) Has some glucocorticoid activity
(5) May cause unacceptable polyuria and polydipsia at doses required to normalize sodium and potassium
2. Prednisone
a. Mechanisms: Precursor of prednisolone with cortisol-like effects
b. Indications: Used for physiologic replacement of cortisol in hypoadrenocorticism
c. Side effects and contraindications: Polyuria, polydipsia, panting, increased risk of infection, muscle wasting, insulin resistance
3. Dexamethasone
a. Mechanisms
(1) 6 to 10 times more potent than prednisone
(2) No mineralocorticoid activity
b. Indications
(1) Substituted for prednisone or prednisolone when sodium retention is a concern
(2) Does not interfere with cortisol assay (unlike prednisone or prednisolone)
c. Side effects and contraindications: Polyuria, polydipsia, panting, increased risk of infection, muscle wasting, insulin resistance

III. Drug for diabetes mellitus
A. Insulins
1. Indications
a. Regular
(1) Most rapid onset and shortest acting
(2) Can be given IV, subcutaneously (SQ), or intramuscularly (IM)
(3) Used for short-term management of diabetics during hospitalization
b. NPH, Lente
(1) Intermediate acting
(2) SQ or IM only
(3) Suitable for twice daily maintenance administration
c. PZI, Ultralente
(1) Slowly absorbed, longer acting
(2) Subcutaneously or IM only
(3) PZI suitable for twice (or sometimes once) daily maintenance administration, in cats especially
d. Glargine
(1) Slowly absorbed, longer acting
(2) SQ or IM only
(3) Fairly flat glucose curve
(4) Glargine suitable for twice (or sometimes once) daily maintenance administration, in cats especially
2. Side effects and contraindications: Hypoglycemia (weakness, twitching, seizures)
B. Oral hyoglycemics: Glipizide
1. Mechanisms
a. Enhances insulin secretion by pancreatic β-cells
b. May enhance peripheral sensitivity to insulin
2. Indications: Nonketotic, mild diabetes in cats
3. Side effects and contraindications: Lack of efficacy, hypoglycemia, GI upset, increased ALT (reversible)

DRUGS FOR RENAL DISEASE

I. Drugs to promote diuresis
A. Mannitol
1. Mechanism of action: Osmotic diuretic
2. Indications
a. Nonobstructive oliguric renal failure
b. Promote diuresis in some toxicoses
c. Also used for glaucoma, increased intracranial pressure
3. Side effects: Nausea, dizziness, volume overload, hyponatremia, hypokalemia
4. Contraindications: Dehydration, active intracranial bleeding, hypertension, pulmonary edema
B. Dopamine
1. Mechanism of action
a. Endogenous catecholamine: Immediate precursor of norepinephrine
b. At low doses: Binding to dopamine receptors leads to renal vasodilation
2. Indications. Sometimes used for oliguric renal failure; efficacy is controversial
3. Side effects: Nausea, vomiting, tachycardia, arrhythmias at higher doses
4. Contraindications: Pheochromocytoma, ventricular fibrillation, tachyarrhythmias

II. ACE inhibitors (e.g., enalapril, benazepril)
A. Mechanisms
1. Inhibit ACE to decrease generation of angiotensin II
2. Secondarily decreases elaboration of aldosterone and antidiuretic hormone (ADH)
B. Indications
1. Hypertension, particularly that associated with renal failure
2. Protein-losing nephropathy, to reduce proteinuria

C. Side effects and contraindications: GI upset; may exacerbate azotemia (if dose leads to hypotension); may worsen hyperkalemia

III. Potassium (e.g., potassium gluconate, potassium citrate, potassium chloride [KCl])
A. Mechanisms
1. K supplementation (principal intracellular cation)
a. Cell tonicity
b. Cell resting membrane potential
c. Muscle contractility
2. K citrate is also an alkalinizing agent. Citrate oxidized to bicarbonate
B. Indications
1. Hypokalemia
2. K citrate only
a. Urine alkalinization (e.g., reduce risk of calcium oxalate uroliths)
b. Metabolic acidosis associated with chronic renal failure
C. Side effects: GI upset; hyperkalemia (if overdosed); alkalosis (potassium citrate)
D. Contraindications: Oliguria or anuria

IV. EPO (human recombinant erythropoietin)
A. Mechanism of action: Stimulates erythropoiesis
1. Increases differentiation and proliferation of red blood cell (RBC) precursors
2. Released in response to renal hypoxia
B. Indications: Anemia of chronic renal failure or due to cancer chemotherapy
C. Side effects: AntiEPO antibodies common in dogs and cats (will lead to arrest of erythropoiesis); hypertension, seizures, iron deficiency, dose-dependent polycythemia. Risk of antibodies may be lower with darbepoietin
D. Contraindications: Untreated hypertension, preexisting iron deficiency

DRUGS FOR LOWER URINARY TRACT DISEASE

I. Phenoxybenzamine
A. Mechanism of action. α adrenergic blocker. Relaxation of internal urethral sphincter
B. Indications
1. Urethrospasm
2. Laminitis in horses
3. Pheochromocytoma with hypertension
C. Side effects: Hypotension, rebound tachycardia, weakness, dizziness, GI distress (constipation in horses), increased intraocular pressure, inhibition of ejaculation
D. Contraindications: Hypotension, equine colic, glaucoma

II. Bethanechol
A. Mechanism of action: Cholinergic agonist
1. Mainly muscarinic receptors; nicotinic signs only if overdose
2. Increases bladder detrusor tone
B. Indications: Urinary retention without obstruction (detrusor atony)
C. Side effects
1. SLUD: Salivation, lacrimation, urination, defecation
2. In case of overdose, bronchospasm, bradycardia can result
D. Contraindications: Urinary obstruction, bladder rupture, asthma

III. Amitriptyline
A. Mechanism of action: Tricyclic antidepressant
1. Blocks serotonin and norepinephrine reuptake
2. Central sedative
3. Central and peripheral anticholinergic activity
B. Indications
1. Spraying in cats
2. Interstitial cystitis in cats
3. Separation anxiety
C. Side effects: Sedation, ataxia, paradoxical hyperexcitability, urinary retention
D. Contraindications. Concomitant use of monamine oxidase (MAO) inhibitors

IV. Phenylpropanolamine
A. Mechanism of action. Primarily an α-adrenergic agonist
B. Indications
1. Incontinence owing to decreased internal urethral sphincter tone
2. Nasal congestion
C. Side effects: Restlessness, irritability, sedation, hypertension, anorexia
D. Contraindications (relative): Glaucoma, hypertension, untreated hyperthyroidism, benign prostatic hypertrophy

V. DES (diethylstilbestrol)
A. Mechanism of action: Synthetic estrogen
B. Indications: Hormone-responsive ("spay") incontinence in dogs
C. Side effects: Bone marrow suppression at high doses, estrus, pyometra at high doses; femininization of males
D. Contraindications (absolute): Food animals; pregnancy

ANTIBACTERIALS

I. Penicillins
A. Examples
1. Penicillin G, amoxicillin, ampicillin, amoxicillin-clavulanate, ampicillin-sulbactam
2. Extended spectrum: ticarcillin, carbenicillin
B. Mechanisms
1. Inhibit bacterial cell-wall synthesis
2. Susceptible to β-lactamases unless formulated with β-lactamase inhibitors such as clavulanate or sulbactam
C. Spectrum
1. Standard penicillins: Good anaerobic spectrum; some gram-positive and gram-negative spectrum; spirochetes (*Leptospira, Borrelia*)
2. Extended-spectrum penicillins: Expanded gram-negative, often including *Pseudomonas*
D. Side effects and contraindications: GI upset common (oral use); penicillin allergy uncommon

II. Cephalosporins
A. Examples:
1. First generation: Cephalexin, cephalothin, cefazolin, cephadroxil

2. Second generation: Cefoxitin, cefotetan
3. Third generation: Ceftazidime, ceftiaxone. Cefpodoxime classified as third generation but does not have typical expanded spectrum

B. Mechanisms
1. Inhibit bacterial cell-wall synthesis
2. Less sensitive to β-lactamases than are penicillins

C. Spectrum
1. First generation: Excellent gram-positive spectrum; lesser gram-negative spectrum; most anaerobes susceptible. *Enterococcus* not susceptible
2. Second generation: Extended gram-negative coverage, plus *Bacteroides*
3. Third generation: Greatly extended gram-negative coverage

D. Side effects and contraindications: GI upset; poor CNS and prostate penetration

III. Fluoroquinolones (Examples: Enrofloxacin, orbifloxacin, marbofloxacin, difloxacin, ciprofloxacin)
A. Mechanisms: Inhibits DNA gyrase, preventing bacterial DNA synthesis
B. Indications
1. Many gram-negatives, *Staphylococcus*
2. *Mycoplasma, Brucella*
3. Good penetration of CNS, eye, and prostate
4. No anaerobic spectrum

C. Side effects and contraindications
1. Cartilage damage in growing animals (especially dogs)
2. Retinal toxicity and blindness with modest overdose in cats (enrofloxacin > orbifloxacin > marbifloxacin)
3. May exacerbate seizure disorders
4. Poorly absorbed orally with cations (iron, calcium, zinc, bismuth, aluminum-containing drugs)

IV. Tetracyclines (e.g., tetracycline, oxytetracyline, doxycycline)
A. Mechanisms inhibit protein synthesis; bind to 30S and 50S ribosomal subunits
B. Indications
1. Rickettsial, *Anaplasma*, and *Mycoplasma* infections
2. *Brucella*, *Chlamydia* organisms
3. Spirochetes (*Leptospira*, *Borrelia*)

C. Side effects and contraindications
1. Tooth enamel discoloration
2. Increase in blood urea nitrogen (BUN; catabolic effect)
3. Diarrhea, intestinal superinfections
4. Outdated tetracyclines can cause renal proximal tubular toxicity
5. Poorly absorbed orally with cations (iron, calcium, zinc, bismuth, aluminum-containing drugs)

V. Potentiated sulfonamides (e.g., trimethoprim-sulfadiazine, ormetoprin-sulfadimethoxine, trimethoprim-sulfamethoxazole)
A. Mechanisms
1. Trimethoprim, ormetoprim: Inhibit dihydrofolate reductase and decrease folate synthesis in susceptible bacteria
2. Sulfonamides: False folate analogues

B. Indications: Some gram-negatives, *Nocardia, Pneumocystis*

C. Side effects and contraindications
1. KCS
2. Idiosyncratic reactions (blood dyscrasias, hepatotoxicity, arthropathy, skin eruptions)
3. May precipitate out in acid urine and cause hematuria

VI. Aminoglycosides (e.g., gentamicin, amikacin)
A. Mechanisms
1. Inhibit protein synthesis
2. Bind to ribosomal 30S subunit
3. Require energy for bacterial uptake

B. Indications: Serious gram-negative infections; no spectrum for anaerobes

C. Side effects and contraindications: Dose dependent nephrotoxicity (monitor daily urine sediments for granular casts); dose-dependent ototoxicity

VII. Metronidazole
A. Mechanisms: Converted under anerobic conditions to a metabolite that is thought to disrupt bacterial DNA synthesis
B. Indications
1. Anaerobic infections
2. Some efficacy for *Giardia* and *Entamoeba* infections
3. Used as part of "triple therapy" for *Helicobacter* infection in some protocols
4. Used as adjunct therapy in the treatment of inflammatory bowel disease

C. Side effects and contraindications: Cerebellovestibular neurologic signs with overdose; anorexia, GI upset

VIII. Macrolides (e.g., erythromycin, azithromycin, tylosin)
A. Mechanisms: Inhibits protein synthesis; binds to 50S ribosomal subunit
B. Indications
1. Erythromycin, azithromycin
a. Anaerobes and gram-positive aerobes
b. *Chlamydia, Mycoplasma* spp.
2. Tylosin
a. Used for colitis in dogs and cats
b. Used in cattle for bovine respiratory disease complex

C. Side effects and contraindications: Tylosin contraindicated in horses (may cause colitis)

IX. Lincosamides (e.g., clindamycin)
A. Mechanisms: inhibits protein synthesis; binds to 50S ribosomal subunit
B. Indications
1. *Toxoplasma*
2. *Mycoplasma, Chlamydia*
3. Anaerobes and gram-positive aerobes

C. Side effects and contraindications: GI upset; esophageal strictures reported in cats given clindamycin capsules

X. Chloramphenicol and derivatives (e.g., chloramphenicol, florfenicol)
A. Mechanisms: Inhibits protein synthesis; binds to 50S ribosomal subunit

B. Spectrum and indications
1. Anaerobes
2. Good penetration of CNS, prostate
3. Florfenicol only: Treatment of *Pasteurella* and *Haemophilus* pneumonias in cattle

C. Side effects and contraindications
1. Dose-dependent bone marrow suppression
2. Chloramphenicol prohibited in food-producing animals because of rare idiosyncratic aplastic anemia in humans
3. Chloramphenicol inhibits the metabolism of barbiturates such as phenobarbital and enhances their effects

XI. Rifampin
A. Mechanisms: Inhibits DNA-dependent RNA polymerase
B. Spectrum and indications: *Mycobacteria, Rhodococcus equi*
C. Side effects and contraindications: Leads to orange color to urine, saliva, tears, sweat; Rapid resistance when used alone

ANTIFUNGALS

I. Azole antifungals (e.g., ketoconazole, itraconazole, fluconazole, clotrimazole)
A. Mechanisms: Block synthesis of ergosterol, an important component of fungal cytoplasmic membrane (ergosterol is not present in mammalian cell membranes)
B. Indications
1. Ketoconazole and itraconazole used for dermatophytes, *Blastomyces, Coccidioides, Histoplasma*, *Candida*, *Malassezia, Cryptococccus.* Poor penetration into CNS, eye, and testes
2. Topical clotrimazole used for nasal aspergillosis
3. Fluconazole used for systemic mycoses, esp. with ocular, prostate, urinary, or CNS involvement
C. Side effects and contraindications
1. Ketoconazole
a. Anorexia and vomiting
b. Mild increases in ALT
c. Inhibits cortisol synthesis. May prevent cortisol stress response
d. Cytochrome P450 inhibitor. Many potential drug interactions
2. Itraconazole
a. Fewer adverse effects than ketoconazole
b. Does not inhibit cortisol synthesis
c. Cytochrome P450 inhibitor. Many potential drug interactions

II. Antibiotic antifungals
A. Amphotericin B
1. Mechanism of action
a. Selectively binds ergosterol (component of fungal cell membrane)
b. Alters fungal membrane permeability (membrane pore formation)
c. Binds with less affinity to cholesterol in mammalian cells
2. Lipid-complex formulation
a. Taken up well by organs of the mononuclear phagocyte system (liver, spleen, and lungs)
b. Decreased nephrotoxicity
3. Indications are systemic mycoses. *Aspergillus* is usually resistant.
4. Side effects and contraindications
a. Administration limited to IV use
b. Nephrotoxicity (direct toxic effect on renal tubular epithelium; renal vasoconstriction decreases glomerular filtration rate [GFR])
c. Fever and vomiting
d. Anaphylaxis
e. Do not use with concurrent renal or hepatic failure
f. Do not use with aminoglycosides or NSAIDs

B. Griseofulvin
1. Mechanism of action
a. Enters fungi through an energy-dependent mechanism
b. Binds to polymerized microtubules and disrupts mitosis. Accumulates in developing keratinocytes and remains in mature keratinocytes until shed
2. Indications: Active against dermatophytes (*Microsporum* and *Trichophyton*); no effect against yeast
3. Side effects and contraindications
a. Cats and particularly kittens have increased risk of: GI upset, bone marrow suppression, neurotoxicity, hepatotoxicity
b. Teratogenic in cats

GLUCOCORTICOIDS

I. Mechanisms of action
A. Bind intracellular glucorticoid receptor and modify expression profile of genes containing the glucorticoid response element (GRE)
B. Catabolic effects on metabolism
1. Increase in gluconeogenesis
2. Decrease in protein synthesis
3. Increased lipolysis or increased lipogenesis, depending on tissue
C. Effects on musculoskeletal system: Enhanced bone resorption; muscle atrophy
D. Effect on CNS: Change in behavior (hyperactivity or somnolence); polyphagia
E. GI effects: Increased acid secretion and decreased gastric mucosal cell turnover
F. Renal effects: Polyuria; increase in potassium and calcium excretion
G. Effect on cardiovascular system: Promote vasomotor tone; maintain capillary integrity
H. Effect on hematopoietic system
1. Thrombocytosis
2. Neutrophilia, monocytosis
3. Eosinopenia, lymphopenia
4. Decrease inflammatory mediators (e.g,: prostaglandins; leukotriens; histamine)
5. Decrease leukocyte phagocytosis, chemotaxis, and antigen processing

II. Indications (many)
A. Inflammatory diseases

B. Immune-mediated diseases
C. Atopy and allergic diseases
D. Treatment of hypoadrenocorticism
E. Hypercalcemia
F. Maturation of fetus lungs before delivery induction

III. Side effects (depend on dose, route, and the duration of the treatment)
A. Polyuria, polydipsia, polyphagia
B. Lethargy
C. Distended abdomen, thin skin
D. Secondary infections
E. Impaired wound healing
F. GI ulceration
G. Diabetes mellitus
H. Induction of serum alkaline phosphatase (dogs)
I. Pancreatitis

IV. Contraindications (absolute)
A. Systemic fungal infections
B. Keratitis, corneal ulcer
C. GI ulceration
D. Late-stage pregnancy
E. Laminitis in horses (active or potential)
F. Abrupt withdrawal after chronic treatment

V. Common preparations
A. Short-acting: Hydrocortisone
B. Intermediate-acting: Prednisone or prednisolone, methylprednisolone, triamcinolone
C. Long-acting
1. Dexamethasone: no mineralocorticoid activity; may be preferable for patients with hypertension, edema, or ascites
2. Betamethasone
D. Esters formulations
1. Alter solubility and duration of action of steroids
2. Succinate or phosphate esters: Last minutes to hours
3. Acetate: Lasts days to weeks. Diacetate, acetonide, pivalate: Last weeks

NONSTEROIDAL ANTIINFLAMMATORY DRUGS (NSAIDS)

I. Mechanisms of action: Inhibition of cyclo-oxygenases 1 or 2 (COX-1, COX-2), leading to inhibition of prostaglandin synthesis from arachidonic acid
A. Antiinflammatory
B. Antipyretic
C. Analgesic
D. Inhibition of platelet aggregation, via COX-1 inhibition

II. Indications: Musculoskeletal pain, postoperative pain and inflammation, fever

III. Side effects
A. Vomiting, diarrhea
B. Gastric ulceration
C. Impaired renal blood flow
D. Hemorrhage due to impaired platelet function
E. Idiosyncratic liver toxicity

IV. Contraindications: GI ulcers, bleeding disorders, compromised renal function, dehydration, liver dysfunction.

V. Specific agents
A. COX-1 and COX-2 inhibitors
1. Aspirin used to prevent thrombosis; common GI side effects at antiinflammatory doses
2. Phenylbutazone
a. Used primarily in horses for musculoskeletal pain and inflammation
b. Side effects: Bone marrow suppression, renal dysfunction (fluid retention to acute renal failure), gastric ulcers.
3. Flunixine: Used in cattle and horses for pain, inflammation, and endotoxemia
4. Piroxicam: Treatment of transitional cell carcinoma and other tumors (dogs)
B. COX 2 preferential: Carprofen, meloxicam, etodolac
C. COX-2 selective: Deracoxib, prevacoxib
D. Dual LOX-5 and COX-2 inhibitor: Tepoxalin

OPIOID ANALGESICS

I. Analgesia
A. Analgesia mediated by binding of mu receptors in the brainstem, and mu, kappa and delta receptors in the spinal cord
B. Mu (μ) receptors. Localized to pain-regulating areas of brain and spinal cord
1. Excellent analgesia (dose-dependent)
2. Sedation and dysphoria
3. Respiratory depression, heart rate depression, hypothermia, and miosis
4. GI side effects include nausea, vomiting, and defecation
C. Kappa (κ) receptors: Brain (cerebral cortex) and spinal cord
1. Mild analgesia
2. Minimal to no sedation
3. Mild respiratory depression
4. Rarely causes vomiting
D. Delta (δ) receptors. Limbic area of CNS and spinal cord
1. Analgesia
2. Decreased GI motility
3. Currently not well understood

II. Full opioid agonists
A. Morphine
1. Mechanism of action. Full μ-agonist (but does interact with all opioid receptors)
2. Indications
a. Analgesia for moderate to severe pain; 3 to 4 hours prolonged anesthesia
b. IM use only. Can cause histamine release with associated vasodilation (hypotension) with IV administration
3. Side effects: Respiratory depression (especially at high doses). Use with caution in patients with severe head injuries, metabolic acidosis, or decreased central respiratory drive. Other side effects: Bradycardia, ileus, hyperexcitability and agitation (cats)
B. Oxymorphone
1. Mechanism of action
a. Morphine derivative

b. Full μ-agonist (but does interact with all opioid receptors). 10 times as potent as morphine
2. Indications
a. Analgesia for moderate to severe pain; provides 1 to 3 hours of pain relief
b. Specifically approved for dogs and cats
c. IM and IV administration
3. Side effects: As for morphine
C. Fentanyl
1. Mechanism of action
a. Synthetic opioid
b. Full μ-agonists
(1) Highly selective for μ receptors
(2) 80 times as potent as morphine
2. Indications
a. Analgesia for moderate to severe pain; duration of action approximately 20 minutes
b. Most commonly given IV as a constant rate infusion
c. Transdermal patches are available for longer term use (up to 3 days)
3. Side effects include respiratory depression and bradycardia
D. Hydromorphone
1. Mechanism of action
a. Semisynthetic opioid
b. μ-agonist
(1) Relative to morphine 5 times as potent
(2) Equal potency to oxymorphone
2. Indications include sedation, analgesia. Shorter duration than oxymorphone
3. Side effects: Respiratory depression, bradycardia, ileus, or vomiting

III. Partial opioid agonists: Buprenorphine
A. Mechanism of action
1. Synthetic opioid
2. Partial μ-agonists. Binds strongly to μ receptors and may be difficult to displace with an antagonist or another μ agonist
B. Indications
1. Analgesia (less profound relative to full μ agonists)
a. Moderate pain
b. Provides analgesia for 4 to 8 hours
2. Can act as an opioid antagonist by displacing pure μ agonists
C. Adverse effects
1. Less respiratory depression
2. More difficult to reverse with naloxone

IV. Opioid agonist-antagonist: Butorphanol
A. Mechanism of action
1. Synthetic opioid
2. Mixed agonist-antagonist: κ-receptor agonist; weak μ-receptor antagonist
B. Indications
1. Analgesia (mild). Duration up to 6 hours in cats and 4 hours in dogs. Duration of acute pain relief is rarely longer than 1 to 2 hours
2. Minimal to no sedation
3. Can reverse effects of μ-agonists. 1:40 antagonist potency compared with naloxone
4. Antitussive in dogs
C. Side effects include mild respiratory depression. Less likely to cause hyperexcitability and agitation in cats.

V. Opioid antagonist: Naloxone
A. Mechanism of action
1. Pure opioid antagonist
2. Binds opioid receptors but has no effect
3. Competitively displaces opioid agonists from receptor, reversing the agonists effect
4. High affinity for μ-receptor
5. Lesser affinity for κ- and δ-receptors
B. Indications. Used as a μ- and κ-opioid receptor antagonist
1. Duration relatively short (20 to 30 minutes)
2. Reverses CNS and respiratory depression and bradycardia from μ-agonists
C. Side effects: Excitement, aggression, hyperalgesia

VI. Other agents: Tramadol
A. Mechanism of action
1. Weak agonistic effect on μ-opioid receptor
2. Marked effect on the serotonergic system. Inhibits serotonin and norepinephrine reuptake
3. Marked effect on the α-2 noradrenergic system
4. Active metabolite (*O*-desmethyltramadol): Has higher potency, and stronger affinity for the μ-receptor
5. Minimal effect on respiratory, cardiovascular, and GI systems
B. Indications: Analgesia (acute and chronic pain)
1. Musculoskeletal pain
2. Mixed nociceptive-neuropathic pain
3. Neuropathic pain
C. Side effects
1. Use not recommended with selective serotonin reuptake inhibitors or monoamine oxidase inhibitors
2. Dose reduction recommended in very old patients and patients with renal or liver disease

ANTICOAGULANTS

I. Heparin
A. Mechanism of action
1. Binds with antithrombin to inhibit thrombin formation
2. At higher doses, also blocks fibrin formation and inactivates factors IX, X, XI, and XII
B. Indications include thromboembolic disease, disseminated intravascular coagulopathy (DIC), and laminitis in horses
C. Side effect is bleeding diathesis. Monitor with APTT; antidote is protamine sulfate
D. Contraindications: Active bleeding or recent CNS injury or surgery

II. LMWH (low-molecular-weight heparin)
A. Mechanism of action
1. Depolymerized fractionated heparin
2. Inhibition of secondary hemostasis, as for heparin
3. Unlike heparin, affects thrombin itself only at high doses
B. Indications
1. As for heparin

2. Longer half-life
3. More predictable pharmacokinetics than unfractionated heparin
4. May have lower bleeding risk than unfractionated heparin

C. Side effects. Does not prolong APTT at standard doses
D. Contraindications: Active bleeding or recent CNS injury or surgery

III. Aspirin
A. Mechanism of action
1. Inhibition of primary hemostasis
2. Irreversible COX-1 inhibitor
a. Inhibits thromboxane A2 (procoagulant factor) synthesis in platelets
b. Prevents platelet aggregation
c. At low doses, does not adversely affect endothelial function

B. Indications: At low dose: antiinflammatory and anticoagulant (more efficient on arterial thrombotic disorders)
1. DIC
2. Pulmonary arterial disease secondary to heartworm infestation
3. Cardiomyopathy in cats
4. Adjunctive treatment in glomerular disease

C. Side effects: Uncommon at low antithrombotic doses

ANTICONVULSANTS

I. Phenobarbital
A. Mechanisms
1. Thought to interact with GABAergic receptors
2. Leads to neuronal hyperpolarization

B. Indications: Epileptic seizures
C. Side effects and contraindications: Hyperexcitability inititally, then sedation; polyuria. polydipsia, polyphagia; induction of serum ALP in dogs; hepatotoxicity in some dogs

II. Bromide
A. Mechanisms: Hyperpolarizes neurons by entry via chloride channels
B. Indications: Epileptic seizures
C. Side effects and contraindications: Hyperexcitability initially, then sedation; polyuria, polydipsia, polyphagia; eosinophilic bronchitis in cats. High chloride intake lowers serum bromide concentrations

ANTHELMINTHIC AGENTS

I. Fenbendazole
A. Mechanism of action
1. Bind to microtubules and inhibit cell division in nematodes
2. Inhibit mitochondrial function in nematodes

B. Indications
1. Dogs and cats: Active against roundworms, hookworms, whipworms, *Giardia* spp., and lungworms
2. Cattle: *Haemonchus, Ostertagia, Cooperia, Trichostrongylus*
3. Horses: large and small strongyles, pinworms

C. Side effects (uncommon). GI upset in horses

II. Febantel
A. Mechanism of action
1. Prodrug for fenbendazole and oxfenbendazole
2. Binds to microtubules and inhibit cell division in nematodes
3. Inhibits mitochondrial function in nematodes

B. Indications: As for fenbendazole
C. Side effects (uncommon)
D. Contraindications: Pregnancy

III. Pyrantel
A. Mechanism of action
1. Depolarizating neuromuscular blocking agent
2. Increases acetylcholine release and inhibits cholinesterase
3. Nicotine-like properties

B. Indications
1. Roundworms and hookworms in cats and dogs
2. Large strongyles in horses
3. Not approved for cattle but effective for *Haemonchus, Ostertagia, Cooperia, Trichostrongylus*

C. Side effects: Uncommon

IV. Praziquantel
A. Mechanism of action: Increase in cell membrane permeability to calcium
B. Indications: Treatment of tapeworms in cats, dogs, and other species
C. Side effects: GI upset; ataxia and pain at injection site with injectable form in dogs
D. Contraindications: Not for puppies and kittens less than 4 weeks old

V. Ivermectins
A. Mechanism of action
1. Semisynthetic analogue of avermectin
2. Potentiates the action of the inhibitory neurotransmitter GABA
a. Nematodes and arthropods have GABA neurotransmission in their peripheral nervous system
b. Mammals have GABA neurotransmission limited to the CNS, and ivermectins are excluded from the CNS in most mammals

B. Indications
1. Horses: Large and small stronglyes, pinworms, roundworms, others
2. Cattle: Roundworms, lungworms, grubs
3. Ineffective in liver flukes and tapeworms (do not use GABA neurotransmission)

C. Side effects (uncommon)
1. Local swelling and pruritus after injection
2. Hypersensitivity reactions to dying parasites

D. Contraindications: Lactating dairy cows

FLEA, HEARTWORM, AND ENDOPARASITE PREVENTION

I. Preventatives
A. Ivermectin (Heartguard and Heartguard Plus)
1. Mechanism of action: Potentiates the action of the inhibitory neurotransmitter GABA
2. Indications

a. Efficacy against infective-stage of heartworm larvae in dogs and cats
b. At higher doses effective as heartworm microfilaricide (not approved for this use)
c. No activity against adult heartworms
3. Side effects
a. CNS toxicity: Mydriasis, depression, ataxia, and coma.
b. Higher incidence of toxicosis in collies and other herding breeds (shelties, Australian shepherds, and Old English sheepdogs)

B. Milbemycin oxime (Interceptor)
1. Mechanism of action: As for ivermectin
2. Indications
a. Effective as heartworm preventative and microfilaricide in dogs
b. Controls infections with hookworms, roundworms and whipworms in dogs
c. Available as combination product with lufenuron (Sentinel)
3. Side effects: Heartworm preventative dose reported to be safe in collies and other herding breeds

C. Selamectin (Revolution)
1. Mechanism of action
a. As for ivermectin
b. Topical administration with systemic absorption
c. Distributed via the blood to sebaceous glands of the skin
2. Indications
a. Endoparasite prevention or control
(1) Prevention of heartworm disease in dogs and cats
(2) Control of hookworms and roundworms in cats
b. Topical adulticide for ectoparasitic treatment or control
(1) Fleas (*Ctenocephalides felis*) in dogs and cats
(2) Ticks (*Dermacentor variabilis*) in dogs
(3) Mange (*Sarcoptes scabiei*) in dogs
(4) Ear mites (*Otodectes cynotis*) in dogs and cats
3. Side effects
a. Localized alopecia in cats (site of administration)
b. Rarely (dogs): Diarrhea, vomiting, anorexia, lethargy, salivation, pruritus, urticaria, erythema, muscle tremors, ataxia, and seizures
c. Safe at heartworm-preventative dose in avermectin-sensitive breeds (collies and other herding breeds)

II. Heartworm adulticides

A. Thiacetarsamide (no longer used in the United States)
1. Mechanism of action: Organic arsenical
2. Indications
a. Heartworm adulticide (*Dirofilaria immitis*) in dogs
b. No effect on microfilaria
3. Side effects: Severe vesicant, nephrotoxicity and hepatotoxicity possible, pulmonary thromboembolism, and GI upset. Narrow therapeutic index; more toxic to cats, use in cats controversial

B. Melarsomine (Immiticide)
1. Mechanism of action
a. Organic arsenical
b. Proposed mechanism is arsenical interactions with sulfhydryl groups in parasite enzymes
2. Indications
a. Treatment of adult heartworms and L5 larvae in dogs
b. Has replaced thiacetarsamide
3. Side effects include pulmonary thromboembolism, depression, anorexia, fever, vomiting, and muscle pain at injection site. Has less hepatotoxicity than thiacetarsamide
4. Contraindications
a. Dogs with class 4 heartworm disease (heartworms present in vena cava and right atrium)
b. Very toxic to cats and not recommended for this species

ECTOPARASITICIDES

I. Agents that kill adult ectoparasites

A. Pyrethrins and pyrethroids
1. Mechanism of action
a. Interfere with parasite peripheral nervous system
(1) Block voltage-sensitive sodium channels
(2) Increase the release of GABA, an inhibitory peripheral neurotransmitter
b. Pyrethrins are natural insecticides produced by certain species of the *Chrysanthemum* plant
c. Pyrethroids are synthetic pyrethrins
2. Indications
a. Effective against flies, fleas, lice, and ticks
b. Rapid knockdown effect with little residual activity
3. Side effects
a. Depression, anorexia, vomiting, hypersalivation, muscle tremors, ataxia, and dypsnea
b. High incidence of toxicity in cats; should not be used in cats

B. Organophosphates (OP)
1. Mechanism of action
a. Bind and inhibits acetylcholinesterase (AchE) via enzyme phosphorylation. AchE is the enzyme that degrades acetylcholine (Ach). Results in the accumulation of Ach at synapse, producing continuous neuronal stimulation and paralysis of the parasite
b. OPs are considered irreversible AchE inhibitors. Phosphorylation is only very slowly reversible. Once phosphorylated enzyme complex is aged, reactivation of the enzyme is not possible
2. Indications (not commonly used since development of safer products)
a. Insecticide (fleas, lice, and flies)

b. Acaricide (mites and ticks)
c. Helminthicide
3. Side effects
a. Low margin of safety
b. Toxicosis resulting from interference with muscarinic and nicotinic neurotransmission
(1) Muscarinic signs: Miosis, lacrimation, salivation, diarrhea, frequent urination, bradycardia, or hypotension
(2) Nicotinic signs: Muscle twitching or fasciculations, weakness, and paralysis
(3) CNS depression or seizures
c. Not to be used in greyhounds, whippets, or Persian cats because of their unique sensitivity
d. Should not be used in young, sick, or pregnant animals
4. Contraindications
a. Not to be used other agents that inhibit AchE or block neuromuscular transmission
b. Not recommended to be used in combination with CNS depressants

C. Carbamates
1. Mechanism of action
a. Inhibit AchE (slowly reversible)
b. AchE is fully reactivated upon hydrolysis
2. Indications
a. Insecticide (fleas, lice, and flies)
b. Acaricide (mites and ticks)
3. Side effects are similar to OP
4. Contraindications are similar to OP

D. Amitraz (Mitaban)
1. Mechanism of action
a. Exact mechanism of action unknown
(1) Possible interference with monoamine oxidase
(2) Activation of the inhibitory transmitter, octopamine
b. Potentially activates α-2-adrenergic receptors, which could contribute to the signs of toxicosis (hyperglycemia)
2. Indications
a. Topical generalized canine demodicosis
b. Insecticide and acaricide in a variety of species
c. Used in many tick collars
3. Side effects
a. Transient sedation
b. Hyperglycemia
c. Signs of toxicosis: Sedation, bradycardia, hypotension, mydriasis, vomiting, and diarrhea. Toy breeds may be more susceptible to CNS signs
4. Contraindications. Dogs less than 4 months of age

E. Imidacloprid (Advantage)
1. Mechanism of action
a. Binds invertebrate nicotinic acetylcholine receptors and blocks neurotransmission
b. Higher affinity for invertebrate receptors relative to mammalian receptors
c. Imidacloprid is not degraded by AchE
d. Applied topically and distributes over the entire coat
2. Indications
a. Topical adulticide
b. Kills fleas but not ticks
c. Combination products available: Imidacloprid plus permethrin (K9 Advantix)
3. Side effects: No toxicity has been reported. Use not recommended in sick or pregnant animals
4. Contraindications. Do not use in animals younger than 16 weeks old

F. Nitenpyram (Capstar)
1. Mechanism of action
a. Binds nicotinic Ach receptors in the postsynaptic membranes and blocks Ach-mediated neuronal transmission, causing paralysis and death of fleas
b. Does not inhibit AchE
2. Indications
a. Oral adulticide
(1) A flea adulticide in dogs and cats.
(2) It does not kill ticks, flea eggs, larvae or immature fleas.
(3) May be effective for treating fly larvae (maggots)
b. Combination products
(1) Nitenpyram and lufenuron
(2) Nitenpyram, milbemycin oxide, and lufenuron
3. Side effects: Not labeled for use in animals under 2 pounds or under 4 weeks of age

G. Fipronil (Frontline)
1. Mechanism of action
a. Binds the GABA receptor and blocks neurotransmission within the insects' CNS
b. Dissolves in the skin oils and is deposited in the sebaceous glands, sebum, and hair follicles covering the skin and fur (topical application)
2. Indications
a. Spot-on adulticide (insecticide and acaricide)
(1) Active against fleas and ticks for 1 month
(2) May have some activity against mites (off label use)
b. Combination products: Fipronil plus methoprene (Frontline Plus)
3. Side effects
a. Toxicity has not been reported
b. Use not recommended in sick, pregnant, or debilitated animals
c. Use not recommended in dogs younger than 10 weeks or cats younger than 12 weeks of age

H. Avermectins
1. Ivermectin
a. Method of action: Potentiates the action of the inhibitory neurotransmitter GABA
b. Indications
(1) Broad spectrum against ectoparasites (grubs, lice, mites, and flies) in horses, cattle, swine, and sheep
(2) Sarcoptic mange and demodicosis in dogs

(3) Otodectic mange mites in cats
c. Side effects: CNS toxicity, lethargy, mydriasis, tremors, and death (generally at very high doses)
d. Contraindications. Collies and other herding breeds (Shelties, Australian shepards, and Old English sheepdogs) with the genetic *MDR1* deletion mutation
2. Selamectin (Revolution)
a. Mechanism of action: As for ivermectin
b. Indications: Topical adulticide for ectoparasitic treatment or control
(1) Fleas (*Ctenocephalides felis*) in dogs and cats
(2) Ticks (*Dermacentor variabilis*) in dogs
(3) Mange (*Sarcoptic scabiei*) in dogs
(4) Ear mites (*Otodectes cynotis*) in dogs and cats
c. Side effects
(1) Localized alopecia in cats (site of administration)
(2) Rarely (dogs): Diarrhea, vomiting, anorexia, lethargy, salivation, pruritus, urticaria, erythema, muscle tremors, ataxia, and seizures
(3) Safe in cats and dogs as young as 6 weeks of age
(4) Safe in avermectin-sensitive breeds of dogs (collies and other herding breeds) at labeled dose

II. Insect growth regulator and development inhibitors
A. Methoprene
1. Mechanism of action.
a. Insect growth regulator that mimics the effects of endogenous juvenile insect growth hormones
b. Maintains the larval stage and inhibits maturation to the pupal and adult stages
2. Indications: Topical flea ovicidal and larvicidal
a. Used to control fleas in dogs and cats
b. Available as a combination product with fipronil (Frontline Plus)
3. Adverse effects: Very low toxicity to mammals
B. Lufenuron (Program)
1. Mechanism of action
a. An insect development inhibitor that interferes with chitin synthesis and arrests flea exoskeleton development
b. Lufenuron is ingested by adult fleas and is passed transovarially to the developing flea egg
c. Developing flea eggs exposed to lufenuron either do not hatch or die during the first molt
d. Lipophilic natures enables accumulation in adipose tissue and is slowly released into the bloodstream
2. Indications: Oral ovicidal and larvicidal
a. Flea-control product in dogs and cats
b. Labeled for use in cats and dogs as young as 6 weeks
c. Can be combined safely with other insecticidal products
3. Side effects: Considered safe in nursing, breeding, or pregnant animals

Supplemental Reading

Bertone JJ, Horspool LJI. *Equine Clinical Pharmacology.* Kidlington, UK, 2004, Saunders.
Carpenter JW. *Exotic Animal Formulary*, 3rd ed. St Louis, 2005, Saunders.
Knottenbelt DC. *Saunders Equine Formulary*, Kidlington, UK, 2006, Saunders.
Papich MG. *Saunders Handbook of Veterinary Drugs*, 2nd ed. St Louis, 2007, Saunders.

10 CHAPTER

Toxicology

Patricia A. Talcott

TOXICANTS AFFECTING THE HEART AND SKELETAL MUSCLE

I. Gossypol
 A. Source
 1. Dairy or beef problem
 2. Cotton plant: *Gossypium* spp.
 3. Whole cottonseed, delinted cottonseed, cottonseed meal, cottonseed cake: Can contain up to 40% protein
 4. Cottonseeds and roots (lesser amount in stems, leaves) contain small black-spotted glands containing 15 pigments
 5. Gossypol, a polyphenolic binaphthalene, is the most abundant pigment
 B. Toxicity
 1. Factors involved: Age and species of animal involved, nutritional status, dietary constituents
 2. Two forms: Free and bound
 3. All gossypol in unprocessed seed is in the free form; protein binding occurs during processing
 4. Toxicoses attributed to free form. Bound form (binds to the ϵ-amino group of lysine, calcium (Ca), iron (Fe), sodium (Na), potassium (K), and octylamine) is not readily absorbed within the gastrointestinal (GI) tract. Speculation exists that the bound form may be converted to the free form in the rumen or stomach
 5. Toxicosis generally results from ingestion of excessive amounts for long periods (i.e., longer than 30 days): Cumulative poison (see this in ruminants)
 C. Animals primarily affected
 1. Calves (younger than 6 months) and adult cows: More common in adults
 2. Broilers, hens may also be affected at high dietary levels. Levels tolerated depend on amount of lysine and methionine present, age and strain of bird, addition of iron salts in the diet
 3. Monogastrics are most sensitive: Dogs, chickens, swine, rabbits, guinea pigs; horses, unknown; adult ruminants are more resistant because of binding of gossypol in the rumen to soluble protein; ruminal detoxification can be overwhelmed with ingestion of high levels of free gossypol
 D. Mechanism of action
 1. Highly lipid soluble
 2. Primarily eliminated in bile (gossypol-iron complex)
 3. Alters intracellular and extracellular potassium levels (↑↓) leading to impaired cardiac function: Drop dead (sinus bradycardia, bundle-branch block, premature ventricular contractions, ventricular fibrillation)
 4. Pathogenesis of focal myocardial necrosis is unknown; congestive heart failure (CHF)
 5. Induces anemia via chelation of iron; may see some erythrocyte fragility (lambs, calves)
 6. Testes: Inhibits lactic dehydrogenase (LDH) enzymes and causes adverse effects on sperm morphology and spermatogenesis
 7. Gossypol appears to be cumulative; the longer the animal is on it, the greater the risk
 E. Clinical signs
 1. Usually appear abruptly. Presentation and onset will depend on dose. Sudden death may occur with no premonitory signs, heart failure signs, or drop in production; diarrhea, reproduction problems, particularly in adult ruminants. The most common herd presentation is a combination of all three over a period of several weeks
 2. Typical signs of heart failure: Weakness, anorexia, dyspnea, coughing, effusions, peripheral edema, exercise intolerance, jugular vein distension, weight loss
 3. Subclinical problems in adults: Colic, diarrhea, decreased milk production, conception failures, poor feed conversion
 F. Lesions
 1. Gross: Consistent with CHF. Sometimes might *not* see lesions. In adult animals, changes will often be nonspecific. Need to post multiple animals. Eventually look for or see the following:
 a. Widespread congestion and edema
 b. Peritoneal, pericardial, thoracic fluid
 c. Edematous lungs
 d. Heart: Pale, mottled epicardium or myocardium with white streaks
 e. Liver: Enlarged, friable, reddish brown or yellow
 f. Icterus, hemoglobinuria may or may not be present

2. Microscopic: Sometimes might *not* see lesions. Look for the following:
 a. Cardiomyopathy: Vacuolation, degeneration, myocardial fiber necrosis; variable inflammatory component
 b. Liver: Diffuse centrilobular necrosis

G. Diagnosis based on history, clinical signs in multiple animals, lack of response to treatment, and quantification of gossypol in feed

H. Treatment
1. Acute scenario: Rare (depends on species); induce emesis, activated charcoal (AC), cathartic
2. Alleviate pulmonary edema and signs of CHF, and minimize stress and long-term effects (e.g., production problems)
3. Remove cottonseed and improve ration (supplement with iron and protein); often problem appears when something else in the ration is changed (e.g,. drop in protein, iron, or protein quality)
4. Losses may continue for 2 to 4 weeks

II. Ionophores

A. Source
1. Feed additives: Monovalent and divalent polyether antibiotics. Given orally, they alter microflora populations, and this leads to increased feed efficiency and rate of weight gain (increased production of volatile fatty acid propionic acid by rumen bacteria and enhances nitrogen retention by improving nitrogen digestibility); decreased incidence of bloat and lactic acidosis (kills off lactobacilli); decreased incidence of bovine pulmonary emphysema (reducing the conversion of L-tryptophan to 3-methylindole by the ruminal bacteria); coccidiostat
2. Examples: Monensin, lasalocid, narasin, salinomycin, maduramicin, semduramicin, laidlomycin, virginiamycin

B. Toxicity
1. Varies between *species* and the *specific ionophore*. Toxicosis may result from a single dose (target and nontarget animals) or can occur after daily lower level exposures (not long though), especially in species where it is legally used as a feed additive
2. All species are susceptible; toxicity and sensitivity vary between products
3. Typical scenario: One-time exposure or daily lower-level exposure; usually a history of feed change within last few days
4. Concurrent use of some drugs (e.g., oleandomycin, chloramphenicol, sulfonamides, tiamulin, dihydroquinolones) will increase therapeutic effect 10-fold and increase toxicity 8-fold. This is due to a decrease in the metabolism of the ionophores; macrolide antibiotics decrease rate of ionophore clearance
5. Affects excitable membranes more than others (e.g., cardiac and skeletal muscle)
6. Will sequester short term in adipose tissue; no long-term sequestration

C. Mechanism of action
1. Absorption from GI tract is low; most passes through feces
2. Rapidly metabolized by liver in first-pass effect; metabolites excreted into bile. Very small amounts enter systemic circulation
3. Forms lipid-soluble complexes with monovalent and divalent cations facilitating transport of them across the membrane along a diffusion gradient. Transports primarily Na into cells (proton exchange results in acidosis and potassium loss). High intracellular Na leads to secondary Ca influx, mitochondrial swelling, inhibition of oxidative phosphorylation, cell necrosis and death. All results in early positive ionotropy (myocardial, skeletal contractility), but later negative ionotropy (skeletal and cardiac muscle dysfunction). Smooth muscle spared; striated muscle pathology predominates

D. Clinical signs
1. Latency period (and signs) varies depending on species, age, diet, ionphore, and most importantly dose: 1 to 2 hours (death with no signs); up to 2 to 3 weeks (death may occur several months later as a result of cardiac or respiratory insufficiency): Average is 12 to 72 hours. Where skeletal muscle pathology predominates, death from respiratory depression occurs within first 48 hours
2. The most common clinical manifestations are partial to complete feed aversion; animals will eat other foods; diarrhea, weakness, ataxia, dyspnea, depression, tachycardia. Signs: Cardiac vs. skeletal: May affect one or other or both, depending on species
 a. Horse: Cardiac predominates, along with GI
 b. Cattle: Cardiac predominates, along with GI
 c. Poultry: Combination of heart and skeletal muscle, along with GI (turkey-chicken knockdown syndrome)
 d. Swine, sheep, dog, cat: Associated with skeletal muscle damage; feed refusal, depression, myalgia, stiffness, ascending muscle weakness; paresis, paralysis, and recumbency. Terminally, may see dyspnea, apnea, dysuria, constipation, and convulsions (rare). Death is usually from respiratory failure. May see mild heart lesions

E. Clinical pathology: Fairly nonspecific
1. Look for ↑ bilirubin
2. May see ↑ creatine kinase, ↑ lactate dehydrogenase, ↑ aspartate transaminase, ↑ glucose, stress leukogram
3. May see electrocardiographic (ECG) alterations (not in poultry): S-T segment depression, T-wave depression, atrial fibrillation. Not helpful in diagnosing because most animals dying with myocardial necrosis have normal ECG 24 hours before death
4. May see myoglobinuria, hematuria, azotemia, hypokalemia

F. Pathologic lesions: Some animals may die acutely, showing no significant lesions. Lesions are most pronounced in animals dying several days after ingestion of a toxic dose

1. Gross: Horse, cattle, poultry (cardiac pathology predominates): Pleural, pericardial, and peritoneal effusions, pulmonary edema, pericardial and epicardial hemorrhages, pale myocardium, ventral edema, enlarged liver. Sheep, swine, dogs, cats, poultry (skeletal muscle pathology predominates): Pale streaking of skeletal muscles (fore and hindlimbs, back, diaphragm; multiple sections), red urine
2. Microscopic: Animals dying peracutely may show no significant lesions. Lesions may have focal distribution, so intense sampling is a must. May see the following:
 a. Heart: Pale myofibers, loss of fiber striation, multifocal vacuolar degeneration and necrosis; variable inflammatory component
 b. Skeletal muscle: Severe degeneration/necrosis of type I muscle fibers
 c. Kidney: Acute tubular necrosis
 d. Liver: Centrilobular necrosis, mild fibrosis, congestion
 e. Sensory and motor neurons: Varying degrees of axonal degeneration and destruction of the myelin sheath; highly time dependent
 f. Pancreas: zymogen granule depletion

G. Diagnosis
1. History of change of feed within 3 days of problems
2. Clinical signs in appropriate species
3. Cardiac or skeletal lesions
4. Feed analysis: Will confirm, especially if present in greater than recommended use levels
5. Feces, serum, bile, liver, and GI contents: Analyze for ionophores
6. Exclusion of infectious, nutritional, and other toxic factors
7. In general, stomach contents and tissues are not useful samples for ionophore analysis in target species. Blood levels are low or undetectable, and accumulation does not occur in tissues to a significant extent. Analysis of tissues may be helpful to indicate exposure in nontarget species. In target animals, no known "normal" and "toxic" levels

H. Treatment
1. Acute scenario: Rare. Decontaminate if appropriate; emesis, activated charcoal (AC) + cathartic, mineral oil. "Supportive" care. Decrease ionophore levels to normal in target animals; do not want to change rumen microflora any more than already have
2. Primarily supportive: Selenium, vitamin E may afford some protection before onset of exposure or signs
3. Long-term problems: Cardiac insufficiency → production loss; skeletal fibrosis → performance loss

III. Macadamia nuts

A. Source: Genus *Macadamia*. Endemic to Australia and Indonesia; cultivated elsewhere (Hawaii, California). Edible kernel of the seeds

B. Toxic dose
1. Mean weight of kernel: 2.5 g
2. Estimated toxic dose: About 5 to 40 whole kernels for a 20-kg dog
3. Some nuts contain cyanogenic glycosides; not used as human food
4. Reported only in dogs
5. Toxic factor unknown

C. Clinical signs
1. Sudden onset: Within 6 to 24 hours after ingestion
2. Clinical signs include joint pain (± swelling), stiffness (straight-legged stance), weakness, ataxia, posterior paresis (forelimbs can be affected), recumbency, depression, anorexia, tremors, dyspnea
3. Recover uneventfully generally within 24 to 48 hours

D. Clinical pathology: Not specific. No evidence of skeletal muscle damage

E. Gross histologic lesions: Unknown; no fatalities reported

F. Diagnosis: History of exposure; clinical signs (posterior paresis, joint pain)

G. Treatment: Decontaminate if appropriate: Emesis, AC + cathartic. Supportive: Intravenous (IV) fluids, analgesics (banamine, carprofen, ketoprofen), antibiotics (amoxicillin)

IV. *Nerium* spp. (oleander), *Thevetia* spp. (yellow oleander)

A. Toxic principles
1. Oleander
 a. Cardiac glycosides (e.g., oleandroside, nerioside, oleandrin, digitoxigenin, neriin, folinerin) with digitalis-like and purgative properties
 b. A compound having antibacterial activity (oleandromycin) and one having a strychnine-like effect (rosagenin) have also been isolated
 c. *Nerium indicum* also contains a steroidal glycoside, odoroside
 d. All parts of the plant are toxic and the toxicity is not lost in drying. Lethal doses have been estimated to be 0.005% body weight of either the green or dried plant material. The plant is very bitter tasting. Smoke from burning plant may be toxic. Most cases of poisoning occur when cuttings are thrown into a pasture or mulch/trash pile - most cases occur when the dried clippings are ingested instead of the fresh green material (too bitter)
2. Yellow oleander contains the cardiac glycosides thevetin A, thevetin B, and peruvoside. All parts of the plant are toxic, with the seeds containing the highest concentrations

B. Mechanism of action: Similar to digoxin and digitoxin. Specific inhibition of the sodium-potassium adenosine triphsophatase (ATPase) system in cardiac fibers, leading to increased intracellular Na concentrations and decreased potassium concentrations. This ultimately leads to alterations in heart rate; interference with electrical conduction and an increase in vagal tone

C. Animals affected: All species are susceptible
D. Clinical signs
1. Appear within 8 hours post-ingestion. Most common: Found dead
2. Include initial lethargy, anorexia, colic, vomiting and diarrhea; severe gastroenteritis (blood may be present), tenesmus, pounding and rapid heart beat, rapid breathing (pulmonary edema), tachycardia, tremors, weakness, prolonged cortical relay time (CRT) and dilated pupils
3. Hyperkalemia is often observed on a chemistry panel
4. May see erythema and irritation to the oral mucosa
5. ECG: Digitalis-like effect on the heart causes a variety of changes, depending on the stage of the disease. It is most common to see sinus tachycardia, which progresses to a first-degree or second-degree atrioventricular (AV) block, often leading to atrial and ventricular arrhythmias (ventricular tachycardias, premature ventricular contractions [PVCs], atrial fibrillation)
6. Extremities become cold because of peripheral vasoconstriction and hypotension
7. Eventual coma and death ensues. True convulsions are rarely seen
8. Toxins are very slowly excreted so treatment may be prolonged (several days to 2 to 3 weeks). Death within 2 to 36 hours of onset of signs

E. Pathologic lesions
1. Catarrhal or hemorrhagic gastroenteritis
2. May see ventral edema; edema around the cardiac vessels, atria, and interventricular septa as well as pale foci and hemorrhage in the myocardium; endocardial hemorrhage with pericardial fluid; subepicardial edema around cardiac vessels. Scattered myocardial degeneration, vacuolation, edema, and necrosis (subendocardial vs. most affected)
3. Look for plant and leaves in stomach or rumen; oleandrin analysis of ingesta
4. May see renal disease secondary to compromised heart function, leading to reduced renal perfusion (azotemia; some renal tubule degeneration and necrosis).

F. Treatment
1. Decontaminate (vomiting, AC, cathartics), if indicated
2. Appropriate therapy for hyperkalemia and arrhythmias (dependent on ECG). Options include administering potassium chloride (IV, 10 mEq/hour), procainamide (IV, 100 to 500 mg/animal), maintain fluid and electrolyte balance, provide oxygen, atropine, propanolol. Fab antibody fragments can be tried in animals; number of vials (dosages) not well described

V. *Digitalis* spp. (foxglove).
A. Toxic principles
1. About 12 cardiac glycosides (e.g., digitoxin, digoxin, gitoxin are most important; also include diginatin, gitorin)
2. The entire plant is toxic and the toxicity is not lost in drying

B. Mechanism of action, animals affected, clinical signs, pathologic lesions (often none; can test for digoxin in serum, blood, GI contents)
C. Treatments are the same as for oleander. One can also try digoxin-specific Fab fragment antibodies. One can also test for digoxin levels in serum, plasma, blood to confirm exposures

VI. *Apocynum* spp. (dogbane)
A. Toxic principles
1. Cardiac glycosides (e.g., apocynin, apocynamarin, pocynein, cymarin) with digitalis-like and purgative properties
2. All parts of the plant are toxic, and toxicity is not lost in drying; 15 to 30 g of plant material is lethal to a horse or cow
3. The plant is very bitter tasting and poisoning occurs when other forage is in short supply

B. Mechanism of action, animals affected, clinical signs, pathologic lesions, treatments are the same as for oleander

VII. *Asclepias* spp. (milkweed)
A. Toxic principles
1. Cardenolides (cardiac glycosides; e.g., uscharidin), a resin galitoxin and various steroid alkaloids
2. The highest level of toxicity occurs before maturity, dropping off somewhat as the plant dries (drying does not eliminate the toxicity). Species with the narrow leaves are generally considered more toxic; however, all species should be considered toxic. The quantity of cardenolide varies with the species
3. The monarch butterfly larvae ingest cardenolides while feeding on milkweeds; may act as a deterrent to vertebrate predators because of the bitter taste and emetic and toxic properties

B. Mechanism of action: The cardenolides, similar to oubain and digitoxin, depress cardiac muscle function by inhibiting Na^+-K^+-activated adenosine triphosphatase
C. Animals affected
1. Sheep most frequently; also cattle, goats, horses, poultry, and rabbits
2. Not palatable and will not consume unless deprived of other forage

D. Clinical signs
1. Within a few hours: Weakness, severe depression, dyspnea, muscle tremors, and ataxia. Convulsions, recumbency, and opisthotonous are common, along with hyperthermia, tachyarrhythmias and mydriasis
2. Death is usually within 24 hours of onset of clinical signs

E. Pathologic lesions: None specific. May see congestion of liver, kidney, and lungs and a hemorrhagic gastroenteritis

F. Treatment
1. Largely unsuccessful. Animals should not be stressed; decontaminate with AC, cathartic, or rumenotomy
2. Potassium chloride, procainamide hydrochloride, quinidine sulfate counteract effects of cardenolides on potassium and sodium adenosine triphosphatase

VIII. *Rhododendron* spp., *Kalmia* spp. (rhododendron, azalea, laurel)
A. Toxic principles
1. Grayanotoxins are a series of diterpenoids (more than 18): Grayanotoxin I (known as andromedotoxin, acetylandromedotoxin, rhodotoxin, and asebotoxin), grayanotoxin II (known as deacetylanhydroandromedotoxin), and grayanotoxin III (known as deacetylandromedotoxin)
2. Other toxicants include rhodojaponins I, II, and III; asebotoxins I, II, and III; pieristoxins A, B, and C; ericoline and asebotine (glycosides); arbutin and rhodothanic acid
B. Mechanism of action
1. Binds to closed Na^+ channels to produce a "slow opening" modified open Na^+ channel. The increase in Na^+ permeability results in decreased resting membrane potentials.
2. Grayanotoxin I increases the influx of Na ions in the brain and heart; grayanotoxin III causes prolonged depolarization in skeletal muscle
C. Animals affected
1. Rare; not consumed unless deprived of other forage
2. The entire plant is thought to be toxic, especially the leaves (even when dried). Prunings can be a source of poisonings
3. All animals susceptible; most poisonings in cattle, sheep, and goats
4. Quantity necessary to produce poisoning in cattle: 0.2 to 0.6% body weight
D. Clinical signs
1. Signs usually appear within 6 hours of ingestion
2. Initially, affected animals show depression, weakness, anorexia, salivation, and repeated swallowing. Vomiting or regurgitation is a characteristic feature resulting from stimulation of the vomiting center via the vagus nerve. This can progress to colic, with tenesmus and grinding of the teeth. Diarrhea usually not a prominent sign
3. Affected animals become progressively bradycardic, hypotensive, dyspneic, weak, and eventually become recumbent. Convulsions and paralysis of the limbs may occur. Death results from progressive central nervous system (CNS) depression and respiratory failure
4. Clinical signs usually persist for 24 to 72 hours. Death can also be due to aspiration (asphyxia) or aspiration pneumonia
E. Lesions
1. Necropsy findings are not specific and consist of mild hemorrhagic enteritis
2. May see pieces of leaves in the GI contents
3. There have been reports describing nephritis, mild liver degeneration, and pulmonary edema
4. Can test for grayanotoxin in GI contents
F. Treatment: No specific treatment. AC and a cathartic (careful if vomiting) or rumenotomy (in valuable animals) may be advised. Supportive therapy: IV fluids and electrolytes, Ca gluconate and antibiotics (prevent inhalation pneumonia). Na channel blockers (quinidine) may be used. Atropine to prevent bradycardia

IX. *Aconitum* spp. (monkshood)
A. Toxic principles
1. Diterpene alkaloids (e.g., aconitine, mesaconitine, hypaconitine, aconine) present in all parts of the plant, especially in the roots and seeds. Toxicity varies with climate and stage of growth, but leaves are most toxic just before flowering
2. Poisoning is rare under range conditions because animals usually do not ingest enough of the plant at any one time. Boiling and soaking hydrolyze the alkaloids into the less toxic benzylaconine derivatives
B. Mechanism of action
1. Activates Na channels in excitable membranes of cardiac, neural, and muscle tissue. Prolonged repolarization induces afterdepolarization with triggered automaticity
2. Cardiovascular disturbances include bradycardia, hypotension, and various arrythmias (ventricular tachyarrhythmias). May progress to a complete heart block
3. Acidosis and hypokalemia may also occur
C. Animals affected: All susceptible; most reports in horses, sheep, cattle
D. Clinical signs: Usually a combination of GI, cardiovascular, and neurologic (sensory and motor). Oral irritation, salivation, nausea, vomition, diarrhea, bradycardia, muscular weakness, restlessness, prostration, convulsions, and death
E. Pathologic lesions: Nonspecific
F. Treatment: Supportive; manage like a cardioglycoside overdose. Atropine and AC. Cardioversion is unlikely to be effective. No single antiarrhythmic drug is consistently effective

X. *Taxus* spp. (yew)
A. Toxic principles
1. Alkaloids, a cyanogenic glycoside, ephedrine, and a volatile irritant oil. Intoxications are attributed to the 10 alkaloids, of which taxine A and taxine B are the most prominent. These alkaloids are rapidly absorbed, metabolized, and excreted as benzoic acid
2. Leaves, twigs, bark, and seed (must be chewed) are all toxic, either fresh or dried. Palatability of plant is low
3. Most occur in the late fall when clippings are available to livestock

4. Lethal dose: Horses and monogastrics 0.1 to 0.2% of body weight; ruminants about 0.5% of body weight

B. Mechanism of action
1. Taxine A and B interfere with cardiac conduction: Inhibits AV conduction, thereby slowing atrial and ventricular rates
2. Thought to affect Ca and Na channels similar to antiarrhythmic drugs and may also cause an elevation in potassium levels

C. Animals affected: All susceptible; most common in cattle, horses, and goats; few reports in dogs

D. Clinical signs
1. Onset is usually fast: Trembling, dyspnea, incoordination, collapse, and acute cardiac failure (within 15 min to 4 hours)
2. Signs can be delayed in ruminants up to 24 to 38 hours
3. Irritant oils may cause abdominal pain, vomiting, and diarrhea
4. Dogs have been known to seize
5. Almost always fatal
6. In humans, often see an atypical bundle-branch block

E. Pathologic lesions. None specific

F. Diagnosis: Death is so acute that plant material is often present in oral cavity of dead animal. Plant material is easily identified in the stomach or rumen contents (may require dissecting microscope). Chemical analysis of taxine from GI contents is available

G. Treatment: None specific; symptomatic and supportive therapy. Atropine sulfate or lidocaine may be of benefit. Decontaminate with AC and Epsom salts

XI. *Zigadenus* spp. (death camas)

A. Toxic principles
1. Steroidal alkaloids (glycoalkaloids and ester alkaloids) similar in structure to the nonteratogenic alkaloids of *Veratrum* (e.g., zygacine). The alkaloids are distributed throughout the entire plant and concentrations vary with respect to stage of growth and environmental influences; highest concentrations are present in the vegetative and pod stages
2. Amount of plant necessary to cause a toxic or lethal dose varies with the species of plant and time of year and species of animal affected. About 0.2% to 0.5% of body weight has been reported as being a toxic dose

B. Animals affected: All susceptible; sheep most commonly affected, followed by cattle

C. Mechanism of action: Similar to *Veratrum*; lowers blood pressure (dilation of arterioles) and decreases heart rate

D. Clinical signs
1. Occur within 1 to 6 hours after ingestion
2. Excessive salivation followed by increased respiration, open-mouth breathing, muscle tremors, ataxia, discharge of frothy saliva from the mouth and nose, dyspnea, and vomiting. Progresses to weakness, incoordination, prostration, convulsion, coma, and death
3. The mortality rate is often high. Animals are often found dead

E. Pathologic lesions
1. No distinct lesions. May see inflammation of the GI tract, congestion of the lungs and kidney, subcutaneous hemorrhage, and focal areas of degeneration of the skeletal muscle and myocardium
2. Alkaloid analysis for zygacine from rumen contents is possible
3. Plant identification from rumen contents is difficult

F. Treatment: Symptomatic and supportive only

XII. *Veratrum* spp. (false hellebore, corn-lily)

A. Toxic principles
1. Twenty alkaloids have been isolated from this plant. The glycoalkaloids and ester alkaloids of concern are concentrated in the root and young shoots, so that the danger of poisoning is greatest in early spring. The alkaloid content decreases as the plant matures
2. Small amounts of the plant ingested can produce clinical signs of poisoning and teratogenicity, but large amounts of the plant need to be ingested to produce death
3. Poisoning is rarely fatal because of vomiting, regurgitation, and poor intestinal absorption

B. Mechanism of action
1. Rapid increase in the permeability of the Na channels at the level of excitable cell membranes
2. Primary result is a lowering of blood pressure and a decrease in heart rate by increasing activity from thoracic chemoreceptors and pressor receptors that inhibit sympathetic outflow and augment vagal influence
3. May see emesis, enhanced peristalsis, and hypoglycemia through some unknown mechanism. Emesis is only prevented by a supranodal vagotomy
4. Teratogenesis (two theories): Selective inhibition of miosis at the neural plate stage of embryogenesis or competitive inhibition of required steroidal hormones that influence the synthesis of specific proteins

C. Animals affected: Most commonly observed in sheep. Cattle will not preferentially graze this, but poisonings have been reported

D. Clinical signs and pathologic lesions
1. Signs of acute intoxication occur within 2 to 3 hours after ingestion. These include vomition, excessive salivation, muscle weakness and incoordination, slow irregular heart beat, slow labored breathing, prostration, convulsions, and death within 6 to 18 hours. Lesions are usually nonspecific in acute cases
2. The type of congenital deformities in lambs is directly related to the stage of fetal development at the time of poisoning: Early embryonic death, cyclopia, tracheal stenosis, cleft palate, arthrogyposis, abortion

E. Treatment: Supportive only. Oxygen, AC, cathartic. Remove animals from the source, and if toxicosis is not severe, animals may recover within 3 to 4 hours

XIII. *Persea* spp. (avocado)
A. Toxic principles
1. Persin leaves, fruit, bark, and seed have all been reported to be toxic.
2. Toxicity is retained in the leaves after drying and toxicity varies between varieties. Only the Guatemalan type and its hybrids have been shown to be toxic. Very few reports in the literature
B. Animals affected: Primarily birds (canaries, cockatiels, budgerigars), although horses, cattle, goats, fish, rabbits, dogs, and sheep have also been affected
C. Mechanism of action: Unknown
D. Clinical signs and clinical pathology
1. Avian: Acute respiratory distress within 12 to 15 hours of ingestion. Subcutaneous edema, hydropericardium, edematous air sacs, generalized congestion, myocardial necrosis
2. Myocardial necrosis: Also in cattle, goats, fish, sheep, and horses
3. Horse: Facial edema, skeletal myonecrosis, and colic
4. A noninfectious mastitis from necrosis of secretory epithelium has been reported in goats and other species
5. Sheep (experimental): Myocardial degeneration and nephrosis
E. Treatment: Symptomatic and supportive only

TOXICANTS AFFECTING THE KIDNEYS

I. Grapes and raisins
A. Source
1. All kinds appear to potentially be a problem
2. Grapes: Fresh grocery store–bought grapes, vine grapes from private yards, grape crushings, fermented grapes from wineries. No unique distribution; all throughout the United States
3. Raisins: Commercial, sun-dried; various brands
4. Term *currant* can refer to grapes and raisins
B. Toxicity
1. Unknown toxin: Mycotoxins, flavonoids, tannins, pesticides, metals, high sugar (15% to 40%). No dose response recognized; most are large exposures, but not all; not all dogs exposed get ill
2. Animals affected: Dogs only (no age or breed predilection); anecdotal cases in few cats and ferrets
C. Mechanism of action: Unknown – genetic predisposition? Idiosyncratic?
D. Clinical signs: Vomiting within 2 hours; other signs include anorexia, diarrhea, depression, lethargy, and abdominal pain. Signs continue for a few days up to 3 weeks
E. Clinical pathology
1. Changes occur within 24 hours to several days
2. Hypercalcemia, hyperphosphatemia, elevated $Ca \times PO_4$ product, elevated blood urea nitrogen (BUN) and creatinine (Cr), polyuria (PU), then oliguria or anuria (± isosthenuria), no urinary crystals
F. Lesions, gross: Nonspecific
G. Lesions, microscopic
1. Proximal renal tubule degeneration and/or necrosis (mild to marked), with 33% to 100% distribution; severity of lesions often does not match clinical picture
2. Distal renal tubules less commonly affected. Tubule basement membranes stay intact.
3. ± Golden brown, irregularly shaped, intracellular "inclusions"
H. Diagnosis: History of exposure, clinical signs (GI, renal), clinical pathology changes, histology lesions (rule out other differentials)
I. Treatment
1. Decontamination: Within 12 to 24 hours of ingestion. Emesis, lavage, AC, cathartic; dependent on clinical signs
2. Asymptomatic: Fluid therapy plus Lasix, combined with monitoring, 48 to 72 hours minimum
3. Symptomatic, typical for renal failure: Aggressive fluid therapy, diuresis, low protein-Ca-P diet, caloric support, continuous monitoring, phosphate binder; address the problems present
4. Monitoring for development of acute renal failure: Ca, P, K, BUN, Cr
5. Bland, low-protein, high-carbohydrate diet; prevent adding to BUN
6. Peritoneal dialysis or hemodialysis; kidney transplant

II. Vitamin D_3 (cholecalciferol) or vitamin D_2 (ergocalciferol)
A. Source
1. Rodenticide: Cereal, flakes, tablets, cakes, briquettes
2. Improperly formulated feed with excess vitamin D (resulted in feed recalls)
3. Overuse of multivitamin supplement (commonly contain ergocalciferol)
4. Plant ingestion (*Cestrum diurnum*, day blooming jessamine, wild jasmine, day cestrum, Chinese inkberry; contain 1,25 $[OH]_2$ cholecalciferol - TX, FL). Others: *Solanum malacoxylon*, *Trisetum flavescens*, Hawaii and southern United States
5. Calcipotriol or calcipotriene (Dovonex): Topical antipsoriatic medication (analogue of calcitriol, 1,25$[OH]_2$ cholecalciferol)
6. Calcitriol overdose (treatment of hypoparathyroidism or secondary hyperparathyroidism)
B. Toxicity: All animals susceptible; relay toxicosis rare
C. Mechanism of action
1. Vitamin D is absorbed rapidly, metabolized to 25-(OH)D in liver (long half-life: 19-28 days); kidney converts to 1,25-$(OH)_2$D (calcitriol; active vitamin D, short half-life: 3 days). Calcitriol increases Ca and P intestinal absorption,

increases osteoclastic resorption, and increases renal reabsorption of Ca
2. All lead to persistent hypercalcemia and hyperphosphatemia, which leads to calcification of tissues

D. Clinical signs
1. Develop within 3 to 5 days post-ingestion of cholecalciferol (may see as early as 6 hours post-ingestion of calcipotriene). Time delay also depends on degree of metabolic activation and overcoming homeostatic mechanisms
2. Initially will see GI and neurologic signs (hypercalcemia → depressed muscular excitability); progressively gets more severe. As the disease progresses, will see cardiac (PVCs, hypertension, conduction disturbances, dyspnea, lung sounds, weakness) and renal involvement or signs (PU, polydipsia [PD], depression, anorexia, vomiting) compatible with mineralization of multiple tissues
3. GI and neurologic signs: Anorexia, depression, lethargy, vomiting, generalized muscle weakness or twitching, constipation or diarrhea (with or without blood), seizures (rare), PU or PD (calciuria)
4. Cardiac signs: Ventricular fibrillation, PR interval prolongation, shortening of QT interval, hypertension, PVCs
5. Renal signs: PU or PD, acute or progressive renal failure. May see medullary washout or nephrogenic diabetes insipidus
6. As disease progresses, calcification occurs and death is usually a result of multiple organ failure (mostly renal, GI, cardiac, respiratory, vascular)

E. Clinical pathology
1. Persistent total hypercalcemia (i.e., more than 12 mg/dL) + calciuria (earliest change). Ionized Ca concentration is also elevated.
2. Persistent hyperphosphatemia: Early and reliable sign in affected horses
3. Other findings: Azotemia (prerenal or renal), hyposthenuria, proteinuria, glucosuria

F. Lesions
1. Gross: Mineralization (raised white or red plaques): Buccal cavity, thorax, lungs, heart, stomach, kidney, aorta, almost any tissue may be involved. Diffuse hemorrhages, ulcerations in GI mucosa
2. Microscopic: Degeneration of renal tubular epithelium or mild glomerular degeneration with mineralization; calcification or necrosis of coronary arteries, atria, gastric mucosa, intestinal wall, parietal pleura, pancreas, bladder, etc.; hypertrophy and hyperplasia of parafollicular cells (C cells)

G. Diagnosis
1. History of potential exposure
2. Compatible clinical signs get worse; multisystemic; or postmortem lesions
3. Persistent hypercalcemia and hyperphosphatemia
4. Rule out other major differentials: Serum levels, screen. Parathyroid hormone (PTH) should be low; 25-(OH)D (will not be elevated with overdose of calcitriol or synthetic forms), serum ionized Ca, parathormone related protein (positive in some malignancies). The 25-(OH)D assay measures both chole- and ergo-calciferols but does not measure calcipotriene, or other analogues of calcitriol
5. Bile, renal cortex: 25-hydroxycholecalciferol

H. Treatment
1. Aim is to normalize serum Ca and P, prevent dehydration and renal insufficiencies, control cardiac arrhythmias, and correct electrolyte imbalances. Length of treatment is dependent on response, and that form of vitamin D is ingested. Hypercalcemia from overdose of calcitriol therapy will resolve fairly quickly after discontinuation of calcitriol because of the short half-life of the compound. Overdoses with cholecalciferol or ergocalciferol may need to be treated for a month or longer due to the long half-life ($T_{1/2}$: 29 days)
2. Decontamination: Emesis, repeated doses of AC, cathartic, gastric lavage, depending on time of exposure
3. Calcitonin or pamidronate disodium
4. Fluid therapy (0.9% saline) at least 2 to 3× maintenance. Monitor renal output
5. Furosemide
6. Prednisone or prednisolone: Primary effect on bone (K, GI tract). Usually for 2-4 weeks
7. Low calcium, phosphorus diet (chicken and rice, Hill's Prescription k/d or s/d)
8. Phosphate binders: Aluminum hydroxide
9. Periodic monitoring: Ca, phosphorus, K, BUN, Cr, ECG

III. Ethylene glycol (EG) and propylene glycol

A. Source
1. Antifreeze (94.6%), heat-exchange fluid in solar collectors and ice rink freezing equipment, brake and transmission fluid, color film processing fluid, electrolytic condensers, skin lotions, taxidermist's preservation solutions, paint, some snow globes
2. Colorless, odorless, water-soluble, sweet tasting; some have bittering agents added (denatonium benzoate, bitrex)

B. Toxicity
1. Typical solutions from the radiator: 50:50; 1 tbsp lethal to a 10-pound cat
2. Occurs all year round. Dogs and cats most commonly affected
3. Mortality can be very high because of difficulty in diagnosing and a narrow timeframe in which to work

C. Pharmacodynamics
1. Absorption: Rapid from GI tract. Peak blood levels: 1 to 4 hours in dog. Half-life: 2 to 10 hours. By 16-24 hours, almost all ethylene glycol is metabolized or excreted (>50% excreted unchanged in urine)

2. Metabolism occurs in liver: Series of oxidation reactions; important to know where you are in the cycle. Diagnostic criteria will vary depending on stage of disease animal is in; helpful to diagnose accurately

D. Mechanism of action
1. Ethylene glycol, glycoaldehyde, glycolic acid cause CNS depression; may lead to coma and death if dose is high enough
2. Metabolites, particularly glycolic acid, induce severe metabolic acidosis
3. Metabolites are cytotoxic to renal tubular cells
4. Renal edema compromises renal blood flow and further promotes renal failure
5. Metabolites interfere with TCA cycle and oxidative phosphorylation
6. Calcium oxalate crystal precipitation in renal tubules lead to mechanical disruption

E. Clinical signs
1. Varies: Time and dose dependent; many overlapping signs
2. Stage 1: Mimics acute ethanol, methanol, other glycol intoxications: 2 to 4 hours post-ingestion. See CNS depression. Signs include nausea, vomiting, depression, ataxia, peripheral neuropathy, PD (rise in serum osmolality stimulates thirst), PU, seizure, stupor, coma, death (if large amount consumed). Less common signs include muscle fasciculations, head tremors, nystagmus. Animals may appear to recover near end of stage 1 due to metabolism of ethylene glycol and glycoaldehyde
3. Stage 2: Metabolic acidosis; 2 to 24 hours post-ingestion. Clinical signs worsen; tachypnea, tachycardia, bradycardia occur
4. Stage 3: Oliguric renal failure 24 to 72 hours (dog), 12 to 24 hours (cat) after ingestion. Signs include depression, vomiting, diarrhea, oliguria or anuria, seizures. Retinal lesions include retinal detachment and edema, anterior uveitis

F. Clinical pathology
1. Abnormalities observed are time dependent. Not specific but consistent for just ethylene glycol. Look for the preponderance of evidence
2. Hyperosmolality: Early in disease process (4 to 12 hours post-ingestion). Elevated osmolal gap (difference between measured and calculated). Other findings include elevated anion gap, and metabolic acidosis
3. Hypocalcemia may appear within 4 to 6 hours. Not always present. Patients can be hypocalcemic, normocalcemia, and hypercalcemic. Acidosis will impact the ionized calcium fraction, causing an increase in ionized calcium
4. Calcium monohydrate oxalate crystalluria: 6 hours (dog), 3 hours (cat) post-ingestion. Sometimes dihydrates are observed. Not always present! (in kidney, but may not see in urine)
5. Renal failure changes: Hyperphosphatemia (may be elevated earlier owing to phosphate rust preventatives added), azotemia, hyperglycemia, hyperkalemia. Proteinuria, glucosuria, isosthenuria, casts observed 12 to 72 hours after ingestion
6. Neutrophilic leukocytosis and lymphopenia: Corticosteroid release secondary to vomiting, CNS depresssion, and metabolic acidosis
7. Hyperglycemia: Inhibition of glucose metabolism and release of epinephrine and corticosteroids

G. Gross lesions: Dehydration, hyperemia of GI tract; swollen or shrunken kidneys (depending on stage of disease), pulmonary edema, ulcers

H. Microscopic lesions: Calcium oxalate crystals (birefringent) within renal tubules; degeneration or necrosis of tubular epithelium (glomerular changes and significant inflammatory changes absent); necrotizing vasculitis, several organs

I. Diagnosis
1. Difficult: Early diagnosis is imperative for a favorable prognosis. Clinicians must have a high index of suspicion
2. History of potential exposure
3. Appropriate clinical signs and clinical pathology (multiple diagnostics): Interpret in light of stage of disease
4. Chemical analysis
 a. Blood-urine-serum-plasma for ethylene glycol; high-performance liquid chromatography (HPLC)
 b. In-house ethylene glycol kits; positive test confirms possible exposure only! Be aware of false-positives and false-negatives
 c. Serum or urine: Glycolic acid (up to 60 hours post-ingestion) or ethylene glycol
5. Renal ultrasound: Halo sign
6. Postmortem or biopsy examination: Renal changes (impression smears, squashed preps); histopathology is diagnostic
7. Fluorescein is usually added to detect radiator leaks; may see in urine, skin, or stomach contents using Wood's light

J. Treatment
1. All treatments require periodic monitoring and adjustments
2. Decontaminate: Emesis (almost always occurring in clinically affected patient), gastric lavage with AC (will bind some)
3. IV isotonic fluid therapy for maintenance and diuresis
4. Ethanol: Competitive inhibitor of alcohol dehydrogenase; OR 4-methylpyrazole (fomepizole-Antizol-Vet); alcohol dehydrogenase inhibitor
5. Sodium bicarbonate: Correct metabolic acidosis if necessary
6. Calcium borogluconate: If hypocalcemic
7. Bland, low-protein, high-carbohydrate diet, oral phosphate binders
8. Peritoneal dialysis, hemodialysis
9. Kidney transplant

K. *Note:* Propylene glycol is safer (less toxic) and is generally regarded as safe (GRAS). Estimated

toxic dose for pets: 3 to 4 × EG toxic dose. Metabolized by alcohol dehydrogenase to L-lactate which enters the gluconeogenic pathways. Other pathways of metabolism have been suggested and may be species specific; will cause acute CNS depression, lactic acidosis, hyperosmolality, and contact dermatitis in sensitized individuals. Also causes Heinz body anemia in cats

IV. *Halogeton glomeratus* (halogeton)
 A. Toxic principles
 1. Soluble Na and K oxalates: On a dry-weight basis, oxalate content is 30% in leaves, 10% in seeds, and 3% in stems. Toxicity increases as the plant matures
 2. Most cases of poisoning occur in the fall when other forage is unavailable and a large amount of halogeton is eaten in a short period. Amount of ingested plant material necessary to induce lethality is highly variable
 3. The plant is not considered to be palatable; may be perceived as salty
 4. Cattle are considered by some to be less susceptible because the ruminal microflora (*Oxalobacter formigenes*) readily metabolizes oxalate to carbon dioxide, formate, and methane
 5. Animals may become adapted to high levels of oxalate in the diet if exposed to gradually increasing concentrations over 3- to 4-day period
 6. The plant can taste salty. Availability of water is a major factor in the occurrence of intoxication; eat the plant more avidly
 B. Animals affected: Sheep, cattle, and horses. However, sheep are more commonly affected because of differences in management practices. Sheep are often kept in large flocks and moved as desired where cattle are usually in open ranges where eating habits are much more selective
 C. Mechanism of action
 1. Originally, death was attributed to hypocalcemia (oxalate combining in vivo with calcium) and renal nephrosis (crystals precipitate in proximal renal tubules)
 2. These phenomena do occur, but death is actually due to a metabolic energy failure; oxalates interfere with lactate and succinate dehydrogenase
 D. Clinical signs and clinical pathology
 1. Within 2 to 6 hours: Excessive salivation, anorexia, depression, dyspnea, ataxia, abdominal pain, muscle fasciculations, prostration, coma, seizures; death usually within 10 hours
 2. See azotemia, hypocalcemia, modest increases in serum LDH, aspartate aminotransferase (AST), and alanine aminotransferase (ALT). Corticotropin-releasing factor (CRF) is a common sequela
 E. Pathologic lesions
 1. Erythema and edema of the GI mucosa, abdominal and thoracic fluid, renal congestion, radially arranged streaks may be seen grossly in kidneys
 2. Necrosis of the proximal renal tubules and collecting ducts with birefringent crystals within the lumen. Crystals can be confirmed for oxalate content using the Pizzolato stain and by treating microincerated sections of tissue with sulfuric acid. Crystals may also be present within vascular spaces; responsible for hemorrhage

V. *Rheum rhaponticum* (rhubarb)
 A. Toxic principles
 1. Oxalic acid, along with soluble K oxalate and insoluble Ca oxalate
 2. The pleasant acidity of the stem comes from malic acid
 3. Rhubarb poisoning is uncommon in the United States
 B. Animals affected: All animals susceptible, including humans
 C. Mechanism of action, clinical signs, pathologic lesions, treatment, prevention, and control: See halogeton
 1. Cooking does not destroy the effect of the oxalates
 2. Oxalic acid is corrosive and contact causes severe irritation, so it is unusual that animals under normal circumstances would find the leaves palatable enough to ingest sufficient quantities to cause a problem
 3. Demulcents may be added to the treatment protocol to protect GI tract mucosa

VI. *Rumex* spp. (dock, sorrel, Indian tobacco)
 A. Toxic principles: Soluble oxalate (may contain up to 13.9% oxalate content on a dry weight basis) and nitrate accumulator. Intoxications are reported infrequently in cattle and sheep
 B. Mechanism of action, clinical signs, pathologic lesions, treatment, prevention and control: Refer to halogeton

VII. *Oxalis* spp. (wood-sorrel, oxalis, lady's-sorrel)
 A. Toxic principles: Soluble oxalates, which give sour or acrid taste to the plant
 B. Mechanism of action, clinical signs, pathologic lesions, treatment, prevention, and control: Refer to halogeton

VIII. *Quercus* spp. (oak)
 A. Toxic principles
 1. Tannins → tannic acid → gallic, digallic, trigallic acids, and pyrogallol (in rumen via decarboxylation) are all toxic
 2. All oaks should be considered potentially toxic. Highest concentrations of tannin are present in early leaf buds, immature leaves, and green acorns. As the leaves and buds mature, the toxicity and palatability decrease. Oak poisoning typically occurs in early spring during periods of inclement weather (blowdowns), and animals do not have access to normal forage. Acorn poisoning typically occurs in late fall
 3. Animals must usually ingest large quantities of the plant material (about 50% of diet) for 2 to 4 weeks or longer before onset of clinical signs.

Animals have been poisoned by drinking water that had oak leaves soaking in it. Oak in some areas is an important source of forage for range cattle because of its high palatability and nutritional value

B. Animals affected: Cattle most common, reported in sheep, horses, goats, and birds
C. Mechanism of action: Toxins thought to be GI, hepatic, and renal toxins. Pyrogallol causes methemoglobinemia in sheep
D. Clinical signs and clinical pathology
 1. Animals are often ill for several days or longer before death
 2. Initial signs include abdominal pain, anorexia, rumen stasis, constipation, PU, PD, thin weak pulse → bloody mucous diarrhea → chronic renal failure (low urine specific gravity, azotemia, hyperkalemia, hypoproteinemia, hypocalcemia, proteinuria, bilirubinuria)
 3. May also see elevations in liver enzymes (LDH, AST, ALP)
 4. Tannins can be measured in the urine
 5. Pyrogallol has been measured in tissues (GI contents, liver, kidney)
E. Pathologic lesions
 1. Evidence of gastroenteritis and nephritis: Perirenal edema and hemorrhage, ascites, hydrothorax, GI edema, hemorrhagic gastroenteritis, pale swollen kidneys. Multifocal necrosis of the proximal convoluted tubules
 2. May see hepatic lesions as well (not as prominent)
F. Treatment
 1. Symptomatic and supportive: Fluid therapy, avoid stress
 2. Provide good-quality feed (alfalfa), supplement with grain mix, vitamin supplements, oral Ca carbonate (limestone: increases pH; oxidizes pyrogallol)

IX. *Amaranthus* spp. (pigweed)
A. Toxic principles
 1. Under appropriate conditions, plant may accumulate soluble oxalates (up to 30% dry weight; leaves have 3× as much oxalate as the stems) and nitrate (up to 4.0% dry weight, all parts of the plant are toxic). The mechanism responsible for the perirenal (and elsewhere) edema and nephrosis is unknown
 2. The plant retains toxicity when dried
B. Animals affected: Swine, cattle; nitrate poisoning only occurs in ruminants
C. Mechanism of action: See nitrate intoxication; Refer to Halogeton for oxalate intoxication. The mechanism of action of the unknown toxicant is obviously unknown
D. Clinical signs and clinical pathology
 1. Swine: Posterior incoordination, weakness, trembling, knuckling at pasterns 5 to 10 days after ingestion. Pigs are usually alert, and appetite remains good. Later, see sternal recumbency, flaccid paralysis, coma, and death (5% to 50% mortality)
 2. Cattle: Signs first appear within 8 to 48 days after ingestion: Diarrhea, lethargy, dehydration, ventral subcutaneous edema, ascites, muscle wasting, PU, azotemia, hyperkalemia, proteinuria. Onset of clinical signs for any animal is variable and dependent on percentage of plant ingested in the diet
E. Pathologic lesions
 1. Perirenal edema, ascites, hydrothorax, edema of the ventral abdominal wall and perirectal area; kidneys may be normal or small, pale with subcapsular petechiae
 2. Widespread degeneration and necrosis of the proximal renal tubules: Distal renal tubules and pars recta less severely affected, dilation of the tubules and large number of proteinaceous casts, some oxalate crystals
F. Treatment: Remove animals from access to plant; less than 10% die after removal (will succumb to chronic renal failure). Treat symptomatically and supportively (avoid stress, fluids, electrolytes)

X. *Lilium* and *Hemerocallis* spp.; lily
A. Toxic principles: Tiger lily (*Lilium tigrinum*), Easter lily (*Lilium longiflorum*), Rubrum lily or stargazer lily (*Lilium speciosum*), Japanese show lily (*Lilium lancifolium*), Asiatic hybrid lily (*Lilium* spp.), and day lily (*Hemerocallis* spp.) have all been documented as causing renal disease in cats. Assume that all lilies have a potential to induce renal problems. Ingestion of all parts of the plant, especially the leaves and flowers, have resulted in illness. Small amounts are capable of causing illness
B. Animals affected: Cats only
C. Mechanism of action, clinical signs, clinical pathology: Acute GI upset (vomiting, depression, anorexia) within 12 hours; renal failure developing within 48 to 96 hours post ingestion. Most cats exhibit fearful behavior. Within the first 12 hours, often see PU; terminally, see anuria. Urinalysis reveals tubular epithelial casts, protein, and glucosuria. Azotemia (Cr levels are often extremely high), hyperkalemia, and hyperphosphatemia; also elevations in ALT, creatine kinase (CK), and AST
D. Pathologic lesions: Extensive degeneration and necrosis of proximal tubules, with numerous eosinophilic granular tubular casts. May see some mild interstitial edema and few scattered mineralized tubules. Vacuolar degeneration of hepatocytes, with some mild biliary hyperplasia has also been reported. Basement membrane stays intact; possibility of regeneration occurring
E. Treatment
 1. Within 6 hours: Decontaminate (emesis, gastric lavage, AC, and a cathartic). Aggressive fluid diuresis early, for a minimum of 72 hours
 2. All recognized cases more than 18 hours post exposure will develop renal failure and die if left untreated. Treat for acute renal failure

TOXICANTS AFFECTING THE RESPIRATORY SYSTEM

I. Paraquat
 A. Source
 1. Dipyridyl herbicide used in agriculture; formulations vary from 5% to 20% concentration
 2. Acts as a direct desiccant of leaf and sheath tissue; after application, the plants begin to dry and leaves drop within 3 to 7 days. Used on many crops
 3. Nonvolatile, insoluble in water, and decomposes slowly over time
 4. Emetic, color (blue green) and odor agent added to some preparations to prevent human consumption
 B. Animals affected
 1. All animals susceptible; most cases reported in dogs and cattle
 2. Toxicosis occurs as a result of gaining access to concentrate small animals (SA) or grazing treated areas large animals (LA)
 C. Toxicity
 1. Exposure can be acute or chronic; oral or dermal (nonintact)
 2. Less than 20% of an ingested dose is actually absorbed through the GI tract. Dermal exposure is very small
 3. Paraquat accumulates in high concentrations in lung. Half-life in lung: 24 hours
 4. About 70% of an absorbed dose is excreted unchanged in the urine, and 30% is biotransformed. Very little is excreted into the milk
 D. Mechanism of action
 1. Paraquat accepts an electron and becomes reduced to the paraquat free radical. This occurs in the pulmonary type I alveolar cells and is catalyzed by NADPH cytochrome P-450 reductase
 2. Reduced paraquat can be reoxidized; when this happens, there is a transfer of an electron to oxygen to form a superoxide anion free radical. Superoxide dismutase catalyzes the conversion of two radicals into oxygen and hydrogen peroxide (first line of defense). If hydrogen peroxide is not eliminated, reacts with free radical to yield hydroxy radicals HO·
 3. The superoxide anion free radical is unstable and breaks down to reactive, singlet oxygen, which reacts with polyunsaturated fatty acids of membrane phospholipids to form lipid hydroperoxides. These compounds are unstable and decompose to form lipid free radicals, which may react with other polyunsaturated fatty acid side chains to initiate a cascade of autocatalytic lipid peroxidation. This leads to membrane destruction and subsequent cell death
 E. Clinical signs
 1. Initial syndrome: GI and pulmonary. Later syndrome: Pulmonary and renal
 2. GI (immediate): Vomiting, depression, diarrhea, oral and GI mucosal ulcers, anorexia
 3. Pulmonary (hours to days after exposure): Tachypnea, dyspnea, cyanosis, moist rales, exercise intolerance
 4. Renal (several days): Anuria, oral ulcers, vomiting, depression, anorexia, abdominal pain. Large exposures: Hepatic, adrenal, and cardiac lesions
 F. Clinical pathology. Nonspecific. Dehydration and renal (hemoconcentration, azotemia, low urine specific gravity, tubular casts, proteinuria, anuria), elevated lipase, inflammatory leukogram
 G. Lesions
 1. Extent and location are dependent on dose and time of death after exposure
 2. Gross: Edema, congestion, and hemorrhage of lungs with atelectasis in acute cases; small and fibrotic lungs in chronic cases; congestion of various organs; areas of ulceration along GI tract
 3. Microscopic. Acute: Intralveolar hemorrhage and edema, necrosis of bronchiolar and alveolar epithelium, with greatest effects seen in type I pneumocytes; renal tubule necrosis; focal myocardial necrosis; adrenal necrosis; hepatic necrosis. Chronic: Hyperplasia of alveolar type II cells and alveolar and interstitial fibroplasia
 H. Diagnosis: History of exposures, GI, pulmonary, renal clinical signs, radiographic changes, gross and microscopic findings; chemical confirmation (serum, plasma, urine, blood antemortem; stomach contents, lung, muscle, liver, kidney postmortem)
 I. Treatment
 1. Decrease absorption (decontamination): Emesis (maybe irritating), bentonite, or AC, cathartic
 2. GI protectants: Kaopectate, sucralfate
 3. Antiemetics
 4. Enhance excretion: IV fluids, furosemide; hemodialysis, peritoneal dialysis
 5. Oxygen may be contraindicated early on (increases production of free radicals).

II. Polytetrafluoroethylene
 A. Source
 1. Polytetrafluoroethylene (PTFE, a synthetic polymer): Nonstick surface in cookware (Teflon, Silverstone)
 2. Also present in domestic boilers, irons, ironing board covers, solid fuel burners, baking sheets, heaters, heat lamps, light bulbs, and others
 B. Animals affected: Most commonly reported inhalant toxicity in birds; other species are susceptible Reported in humans, rats, mice, dogs, monkeys, guinea pigs, rabbits, chickens, quail, and pheasants. Syndrome has been referred to as *polymer-fume fever*
 C. Toxicity
 1. PTFE is relatively heat stable and safe at temperatures below 280° C or 500° F (boiling water, 213° F)
 2. Above this temperature, PTFE undergoes pyrolysis and releases toxic fumes (e.g., carbonyl fluoride, perfluoroisobutylene, hydrogen fluoride) and particulates
 D. Mechanism of action: Direct irritants to respiratory tract
 E. Clinical Signs. Pulmonary: Shortly after exposure (within 1 hour). Signs include choking, regurgitation of fluid, ataxia, trembling, followed rapidly by death

F. Lesions: Gross or microscopic; extensive pulmonary congestion, edema, and hemorrhage; severe pneumonitis
G. Diagnosis: History of overheating PTFE, pulmonary clinical signs, gross lesions of acute inhalant exposure to irritant
H. Treatment: Fresh air, oxygen; diuretics

III. 3-Methyl indole: Acute atypical pulmonary emphysema and edema, fog fever
A. Description and habitat: Occurs in cattle when moved from a dry to a lush, green pasture; common in the fall. Commonly implicated forages include alfalfa, kale, rape, turnip tops, rapidly growing pasture grass
B. Toxic principles, mechanism of action, animals affected
1. D,L-tryptophan is converted in the rumen to indolacetic acid, which is converted to 3-methylindole. 3-Methylindole is absorbed and metabolized by the MFO system of the lung; directly affects cells and cell membranes of bronchioles and alveolar walls
2. Adults most commonly affected; calves more resistant
C. Clinical signs: Typically within 24 to 36 hours; acute respiratory distress, death
D. Pathologic lesions: Edema, interstitial emphysema, hyaline membranes, hyperplasia of the alveolar lining cells
E. Diagnosis: Pathologic lesions. 3-Methylindole has short half-life, so testing is futile

TOXICANTS AFFECTING THE LIVER

I. Copper (Cu) toxicosis
A. Source
1. Large animals
a. Feeding complete feeds or mineral mixes formulated for swine, poultry, or cattle to susceptible animals
b. Mixing errors: Too much copper; not enough molybdenum (Mo), sulfur, iron, nitrate, or zinc
c. Nonspecific liver dysfunction (tumor, pyrrolizidine alkaloids) can result in failure to metabolize copper
d. Dietary trace element imbalance: Forages adequate in copper, low in molybdenum
e. Plants contaminated with copper-containing pesticides (copper sulfate)
f. Water contaminated with algicides, footbaths
g. Grazing on copper-contaminated soils; mining and refining operations
h. Grazing on pastures fertilized with swine or poultry manure; copper growth promotants
i. Injectable copper products
2. Small animals, exotics
a. Coins: Pennies minted up to 1982 contain 95% copper, 4% zinc, 1% iron and lead; nickles contain 75% copper; dimes, quarters, and half-dollars contain 92% copper. Canadian pennies up to 1997 contain 98.5% copper. Do not seem to dissolve like the zinc pennies
b. Others: Paints, pesticides, wire, jewelry, copper sulfate
c. Preexisting hepatic disease
B. Animals commonly affected
1. All animals have potential to be exposed to copper toxicosis
2. Acute toxicosis: Cattle receiving copper disodium edetate injectable product; massive exposure: Dog, cat, goose, cow, almost any species; unusual
3. Subchronic or chronic toxicosis: Puppies, small breed dogs, cats, exotics, ingestion of coins. Coins do not appear to leach as quickly as the zinc ones
4. Subchronic or chronic toxicosis: Preruminant calves, sheep (breed susceptibility, Suffolk, Rambouillet), camelids and goats in between; adult cows, swine, and horses relatively resistant
5. Copper storage disease: Bedlington terriers (affects 40% to 60% of breed). Autosomal recessive. West Highland white terriers, Dobermans, cocker spaniels, others. This is due to inability to metabolize not to excess amount in diet
C. Toxicity
1. Onset of signs are often acute, though exposures are typically chronic
2. Complex interaction between copper, molybdenum, and sulfate. Iron, zinc, and selenium can also interfere. Ratio of copper:molybdenum in diet is important in LA - 6:1 normal. Ratio greater than 10:1 may result in copper toxicosis
3. Molybdenum and sulfate will tie up copper to prevent excessive absorption and accumulation. Toxicosis is often precipitated by stress
D. Mechanism of action
1. Absorbed by small intestine (competes with zinc). Most copper is absorbed by active transport (diffusion can occur at higher concentrations). The intestinal mucosal cells regulate copper transfer into the portal circulation, in part by the use of intracelluar metallothionein. As copper levels increase, synthesis of metallothionein increases, which binds copper and prevents it from going into circulation. The copper is lost when the mucosal cell is sloughed from the intestinal lining. Before secretion into circulation, the copper is mostly bound to albumin
2. When it reaches the primary organ of metabolism, the liver, the copper is distributed among four intracellular pools: Biliary pool, ceruloplasmin (copper transport protein), metalloenzymes, and copper-metallothionein complexes. If excessive copper-metallothionein is present, it is stored by lysosomes
3. Liver metabolizes copper if sufficient molybdenum and sulfate available and is excreted mainly into the bile as a Cu-Mo-SO_4 complex
4. If storage capacity of liver is exceeded, some stressful event usually precipitates release of copper from lysosomes into the cytoplasm

resulting in hepatocellular death (Cu induced free radical damage). When hepatocytes die, copper is released into the circulation and causes premature death of the erythrocytes
5. End result: Acute hemolytic crisis (not seen some species or in some cases – reports in goats and llamas)

E. Clinical signs and clinical pathology
1. Chronic exposures, acute onset of signs: Sporadic occurrence (group problem)
2. Anorexia, weakness, hunched-over appearance, increased respiratory rate, red urine, icterus, recumbency, production losses (poor weight gain, drop in milk production)
3. Clinical pathology findings include hemoglobinemia, hemoglobinuria, hyperbilirubinemia, anemia, elevated methemoglobin levels (30%-40%; do not confuse with nitrate). Elevated AST, γ-glutamyltransferase (GGT), LDH, succinate dehydrogease (SDH), arginase; often are elevated 6 to 8 weeks before hemolytic crisis; may return to normal 1 to 2 weeks before crisis, then rise again 24 to 48 hours before observance of clinical signs

F. Lesions
1. Gross: Icterus; enlarged, discolored kidneys; enlarged, friable, tan liver; enlarged, engorged spleen; distended gallbladder; gastroenteritis if acute (erosion and ulceration of the abomasum)
2. Microscopic: Centrilobular and periacinar hepatocellular vacuolation and necrosis, portal fibrosis, lot of granular gray-green pigment within Kupffer cells; renal cortical tubular and glomerular degeneration and necrosis; gastroenteritis if acute; hemoglobin casts in tubules

G. Diagnosis
1. History of potential exposure: Determine length of exposure period (feed change within last several months)
2. Appropriate clinical signs, sporadic occurrence. Not often a flock or herd outbreak, although it is a flock or herd problem. Assess liver enzymes in rest of animals; liver biopsy
3. Postmortem lesions, gross and microscopic
4. Radiographs: Look for metallic object
5. Chemical analysis
 a. Elevated serum-plasma copper levels. Levels normal 24 to 48 hours before hemolytic crisis. May be quite variable. Poor diagnostic tool
 b. Liver and kidney copper concentrations. The longer the exposure, the higher the levels. May not see high levels in acute exposures. Levels may be variable. Liver is the storage tissue; kidney says it is mobilizing
 c. Forage, supplement, water analysis (Cu, Mo, SO_4, Fe): Identify source and dietary ratios

H. Treatment
1. For clinically affected animals as well as for prevention: Prognosis is generally poor. The Food and Drug Administration (FDA) does not allow the use of ammonium sulfate and sodium thiosulfate to deplete liver copper; permissible to use sodium molybdate and gypsum
2. Supportive: Blood transfusions, analgesics, fluids; dependent on clinical presentation and species affected
3. D-penicillamine (Cuprimine): Enhances urinary excretion. May see exacerbation of clinical signs due to redistribution of copper
4. Provide some source of Mo and sulfate (and maybe iron and zinc): Do for ill and normal animals
5. Zinc: Supplement ration. Zinc will induce intestinal cell metallothionein, which complexes endogenous and exogenous copper and traps it in the cell until the intestinal cell is sloughed. Removal of hepatic copper is achieved gradually as depleted plasma copper is restored from the liver

I. Copper storage disease in Bedlington terriers and other breeds
1. Most common syndrome: Dogs older than 2 to 4 years of age with chronic, recurrent bouts of hepatitis: Anorexia, vomiting, weakness, lethargy, weight loss. If severe, see ascites, hepatic encephalopathy. Hemolysis: Not seen
2. Affected dogs often have liver copper levels greater than 400 ppm. Best diagnostic indicator is liver enzyme elevations and elevated bilirubin concentrations at the time of clinical disease and liver biopsy histology lesions + copper levels. Generally see no increase in serum copper levels in affected dogs. Carrier state-progeny testing program identifies carrier animals by analyzing fecal 64Cu 48 hours after a single IV dose for the Bedlington terriers where the disease is know to be an autosomal-recessive disease. Geneticists have located the gene responsible → simple blood test for dogs
3. Treatment
 a. Chronic administration of D-penicillamine. Trientine (2,3,2-tetramine tetrahydrochloride) is an alternative
 b. Glucocorticoids: Lysosomal stabilization during the acute stages
 c. Ascorbic acid: Enhances urinary copper excretion
 d. Zinc acetate: Daily; requires periodic monitoring of serum zinc
 e. Reduce oxidant stress: Vitamin E, S-adenosylmethionine, Actigall, dietary modification.

II. Aflatoxicosis

A. Source
1. Aflatoxin, a bisfuranocoumarin compound, produced by some strains of *Aspergillus flavus* and *parasiticus* is an example of a mycotoxin
2. Four predominant forms: aflatoxin B_1, B_2, G_1, G_2 (M_1 is the milk metabolite of B_1)
3. Frequently contaminated feed: Corn, peanuts, cottonseed, walnuts, pecans, almonds, grain sorghum; high levels in damaged or broken grains (screenings)
4. Can occur as field fungi or storage fungi

B. Toxicity
 1. Sensitivity depends on species, age, and sex
 2. Reported most commonly in cattle (even though not very sensitive), swine, birds (domestic and wildlife) (hemorrhagic anemia syndrome)
 3. A few outbreaks have occurred in dogs from contaminated dog food
 4. Can see with dogs ingesting moldy food items (e.g., bread)
 5. Dose determines whether problems are acute or chronic problems

C. Mechanism of action
 1. Potent hepatotoxin, nephrotoxin, immunosuppressant, hepatic carcinogen; requires metabolic activation
 2. Being a human carcinogen, there is a concern about aflatoxin residues in meat and milk destined for human consumption

D. Clinical signs
 1. Very dose dependent
 2. Acute: In most animals, anorexia, depression, reduced gain and milk production, liver damage. Have been reported in dogs: Vomiting, hepatocellular damage, death
 3. Chronic: Loss of production (gain, milk), rough hair coat, depressed appetite, intermittent diarrhea, anemia, jaundice, poor fertility (abortions, early embryonic death, decreased conception rates), depression, intermittent pyrexia, anorexia, increased prevalence, severity of infectious disease

E. Clinical pathology
 1. Elevated liver enzymes: ALT, AST, alkaline phosphatase, ornithine carbamyl transferase, sorbitol dehydrogenase. Elevated bile acids
 2. Decreased BUN, albumin, and albumin-globulin (A:G) ratio
 3. Decreased clearance of bromosulfophthalein

F. Lesions
 1. Gross: Icterus, ascites, intestinal hemorrhage, general debilitation. Pale yellow to orange, friable, nodular liver
 2. Microscopic, acute: Massive liver necrosis. Chronic: Biliary hyperplasia, hepatocytomegaly, hepatic lipidosis, fibrosis, nephritis, congestion of renal tubular sinusoids, and degeneration of proximal tubular epithelium in poultry

G. Diagnosis
 1. History of feeding susceptible feedstuffs. Correct species, age, sex, clinical signs, and lesions
 2. Feed and tissue analysis. Representative sampling of feed is a must
 a. Black light screening: Many grain buyers and sellers use this
 b. Assess fungal growth (colony forming units): Valid parameter to assess hygienic quality but cannot predict level of mycotoxin contamination
 c. Enzyme-linked immunosorbent assay (ELISA) tests: Screen is very matrix specific; good screening test
 d. Feed chromatography quantification confirms the screening methods
 e. Liver, kidney, lung: Aflatoxin residues

H. Treatment: Change to aflatoxin-free diet; provide good nutritional support, stress free

III. *Cyanobacteria (Microcystis*, *Anacystis, Nodularia, Oscillatoria)*

A. Source
 1. *Microcystis* or *Anacystis aeruginosa* (most common): Stagnant, eutrophic ponds, lakes, watering holes
 2. Require very specific environmental conditions for both growth and toxin production: Phosphate, nitrate, sulfate for optimum growth; temperature, pH, period of about 5 days of "quiet" weather; allows algae to fill with oxygen and concentrate on the surface
 3. All animals are susceptible; become exposed when wind concentrates toxic amount of bloom along shoreline

B. Toxicity
 1. Fresh *Microcystis-Anacystis* blooms are green. As deteriorate, change to blue-green or blue. Other blue-green algae can be red, black, or a variety of colors. *Oscillatoria* can be pink to red. Colors vary depending on the pigments being produced; these *Cyanobacteria* have plant and animal characteristics
 2. Microcystin (7 aa), nodularin (5 aa) : Cyclic peptides. Released when cell dies or there is a change in cell membrane permeability

C. Mechanism of action
 1. Hepatocytes primary targets because of specific carrier-mediated uptake. The toxins alter phosphorylation of cytoskeletal components (interfere with phosphatases), thereby disrupting organization of actin filaments. Unchecked activity of the kinases and excessive phosphorylation of the intermediate filaments and microfilaments increase the rate of subunit loss and dissociation. This interrupts hepatocyte interactions with neighboring cells, breaking contact with other hepatocytes and with sinusoidal capillaries
 2. Intrahepatic necrosis and hemorrhage; severe circulatory shock and death

D. Clinical signs
 1. Acute ingestions within 1 to 4 hours. Signs include vomiting, abdominal pain, diarrhea (with or without blood), weakness, pallor, petechiation-ecchymoses, death (in less than 24 hours). Often within 1 to 2 hours see circulatory collapse, shock. Several hours later see liver failure, disseminated intravascular coagulopathy (DIC)
 2. Sublethal ingestions: Horses, ruminants; hepatogenous photosensitization

E. Clinical pathology: Liver changes include elevated liver enzymes (severe), elevated bile acids, decreased protein, decreased BUN, hyperbilirubinemia

F. Lesions
 1. Gross: Liver, swollen, edematous, blood-filled (enlarged 30% to 50%)

2. Microscopic: Liver, acute hepatocellular necrosis; no one particular pattern

G. Diagnosis
1. History of potential exposure to an appropriate water source and appropriate weather pattern
2. Appropriate clinical signs: Acute cardiovascular collapse and liver failure
3. Compatible gross and microscopic lesions
4. Algae identification
 a. Examine immediately under light microscope
 b. Fix in equal amounts of 10% buffered formalin; later identification
 c. Freeze or refrigerate 2 L of concentrated algae bloom, gastric contents, liver for toxin analysis; can be expensive
 d. Refrigerate for culture
 e. Fresh sample for bioassay

H. Treatment: Decontaminate (AC, saline cathartic, cholestyramine for small animals); combat shock (IV fluids, transfusion, corticosteroids)

IV. Iron (Fe)

A. Source: Iron-containing supplements, multivitamins, fertilizers, moss repellants, molluscicides; acute poisoning uncommon

B. Toxicity: Most commonly reported in dogs. Iron form is important; there are soluble forms and insoluble forms (metallic iron, ferric oxide [rust])

C. Mechanism of action
1. Iron is absorbed from the gut in a two-step process. The iron is first taken up by the gastric mucosal cells; this is thought to be a carrier-mediated process. Then iron is either transferred into circulation, where it is bound to transferrin or is lost through the feces when the mucosal cells are sloughed. Transferrin transports iron where needed. In cases of excess exposure, too much iron gets access to systemic circulation and the protein-binding capacity of transferrin is overwhelmed, and iron can then interact with cellular constituents. Some is bound to ferritin, an iron-storage protein in tissues, but this is overwhelmed in acute exposures
2. Long-term chronic low-level exposures causing excess iron stores are in the form of ferritin or hemosiderin, liver
3. Free radical formation leads to GI damage, vascular damage, hepatic damage, and cardiac damage. This can lead to other more serious systemic wide problems

D. Clinical signs
1. Acute (within 0 to 6 hours): Vomiting, abdominal pain, depression, diarrhea (with or without blood). Within 6 to 24 hours, apparent recovery
2. Within 12 to 96 hours: GI, vascular, hepatic, cardiac signs including muscle tremors, shock, weakness, tachypnea, pallor, petechiation-ecchymoses, coagulation disorders, death

E. Clinical pathology
1. Nonspecific changes; dependent on organ affected
2. Findings include elevated liver enzymes, elevated bile acids, decreased protein, decreased BUN, hyperbilirubinemia, metabolic acidosis, changes consistent with dehydration

F. Lesions
1. Gross: In the GI tract, erythema, necrosis and sloughing, hemorrhage; peripheral edema; hemorrhage. In the liver, hemorrhage, necrosis
2. Microscopic: Necrosis of the mucosal epithelial cells, myocardium, vascular epithelium, and hepatocytes

G. Diagnosis
1. History of potential exposure
2. Appropriate clinical signs; multiple systems affected
3. Compatible gross and microscopic lesions
4. Complete blood cell count (CBC), serum chemistry panel, radiographs (look for nondissolved tablets)
5. Confirmation: 4 to 6 hours after ingestion: total serum iron (nonhemolyzed sample), total iron binding capacity

H. Treatment: Decontamination (emesis, lavage, gastrotomy); supportive care (fluids, electrolytes, GI protectants, acid-base). Give deferoxamine (Desferal) within first 12 hours if serum iron is greater than 300 μg/dL

V. Xylitol (five carbon sugar alcohol [pentitol], sucrose substitute)

A. Source: Baked goods, desserts, toothpaste and other oral care-hygeine products, gum, candy; granulated powder for cooking and baking

B. Toxicity: Major problem in dogs: questionable in other species

C. Mechanism of action: Rapid severe increase in blood insulin → hypoglycemia; cause of hepatotoxicity is unknown

D. Clinical signs
1. Acute (within 30 to 60 minutes): Hypoglycemia, weakness, ataxia, seizures, vomiting, diarrhea, increased intestinal gas
2. Within 9 to 72 hours: Hepatic failure; weakness, depression, vomiting, lethargy, petechial and ecchymotic hemorrhages, abdominal pain, seizures, hemorrhage (DIC or secondary to liver failure).

E. Clinical pathology: Hypoglycemia (may be severe), hypokalemia, elevated liver enzymes (ALT, ALP, LDH), hyperbilirubinemia, hyperphosphatemia, prolonged clotting times, thrombocytopenia, elevated bile acids

F. Lesions. Gross: Widespread hemorrhages (petechial and ecchymotic), hepatomegaly. Microscopic: Diffuse hepatic necrosis, bile duct hyperplasia, pulmonary edema

G. Diagnosis: Exposure, clinical signs, hypoglycemia, gross/microscopic lesions

H. Treatment
1. Decontamination: Based on timing; emesis (before there is a risk of aspiration), lavage
2. Supportive care based on problems: Oral sugar supplements, dextrose IV, monitor, liver protectants, transfusions
3. Monitor: Glucose, liver enzymes, total bilirubin, platelet counts, clotting times

VI. *Xanthium strumarium* and *spinosum* (cocklebur, heartleaf cocklebur, sheepbur)
 A. Toxic principles
 1. Carboxyatractyloside (sulfated glycoside) is present in the highest concentration in the seeds. Seeds rarely cause poisonings because they are found in the burs, which are not normally eaten
 2. Carboxyatractyloside is distributed into the palatable dicotyledons, or two-leaf seedling stage, as the seed germinates. Poisonings are most commonly observed in animals grazing this stage in early spring or summer when other forage is unavailable. Toxicity wanes as the plant matures
 B. Mechanism of action: Not well defined. May act as an uncoupler of oxidative phosphorylation
 C. Animals affected: Swine, cattle, and sheep most commonly affected
 D. Clinical signs and clinical pathology
 1. Onset of clinical signs varies with amount ingested: 12 hours to 2 days
 2. Typical signs include anorexia, weakness, acute depression, nausea, vomition, dyspnea, opisthotonous. This may progress to spasmodic muscle contractions and running motions, recumbency, convulsions and death 2 to 7 days later. Blindness and hypersensitivity have been reported in cattle
 3. Leukopenia, icterus, hyperglycemia, azotemia, elevated LDH, AST, ALT, CPK, hypocalcemia, hypokalemia, hyponatremia, hypochloremia
 E. Lesions
 1. Gross lesions include ascites, abnormal discoloration and mottling of the liver and kidney, and GI congestion and irritation. May see a "cherry-red" coloration to the viscera
 2. Microscopic lesions include severe acute centrilobular hepatocellular necrosis and degeneration, hepatic lipidosis, proximal renal tubular degeneration and necrosis, and ischemic neuronal degeneration and edema (reported in swine only)

VII. Pyrrolizidine alkaloid (PA)-containing plants: *Senecio* spp., *Amsinckia intermedia, Cynoglossum officinale, Heliotropium curassavicum*
 A. Toxic principles
 1. Toxic pyrrolizidine alkaloids: Many have been isolated and characterized. The pyrrolizidine alkaloids vary between species of plant, genera of plant, and the concentrations vary within each individual plant depending on age and maturity, part of plant, and environmental conditions
 2. Toxicity varies greatly depending on species and age of plant and species of animals affected. In general, toxicosis may result from grazing heavy stands, ingesting seeds in grain mixes, or eating contaminated hay for long periods (i.e., 30 days to several months)
 3. The pyrrolizidine alkaloids can cross the placenta and affect the developing fetus and are also excreted into the urine and milk. Some of these alkaloids have been shown to be carcinogenic, so there is quite a bit of human health concern
 B. Animals affected
 1. Cattle, horses, and swine most commonly affected
 2. Sheep and goats are relatively resistant, either due to altered rumen degradation or differences in hepatic metabolism
 C. Mechanism of action
 1. All pyrrolizidine alkaloids are rapidly absorbed from the GI tract and immediately undergo metabolism within the liver by the mixed function oxidase system to the actual ultimate toxic metabolites, which are highly reactive pyrroles
 2. The pyrroles alkylate macromolecules within the hepatocytes (which are readily available), primarily deoxyribonucleic acid (DNA), which thus impairs cell division. The cell continues to grow and both the nucleus and cytoplasm expand (hepatocytomegaly and karyomegaly) but is unable to divide. Ultimately a critical mass is reached and cell necrosis begins. The toxic effects are cumulative in nature
 D. Clinical signs: Dependent on degree of liver damage: Weakness, loss of condition, weight loss, icterus, crusting and scaling of skin (secondary photosensitivity); hepatic encephalopathy (derangement, mania, drowsiness, yawning, walking aimlessly, ataxia)
 E. Clinical pathology: Elevation in glucose dehydrogenase (GDH), GGT, and ALP
 F. Pathologic lesions
 1. Grossly, liver may be enlarged or cirrhotic, depending on acute or chronic
 2. Histologically, hepatocytomegaly, bile duct proliferation and fibrosis (regenerative response to death of large numbers of hepatocytes) are the predominant features
 3. Analysis of liver and blood for presence of pyrroles is available
 4. Megalocytosis not specific for PA; can see with aflatoxin, nitrosamine, and lantana

VIII. *Kochia scoparia* (fireweed, summer cyprus, burning bush)
 A. Toxic principles
 1. Plant may contain nitrates, soluble oxalates, a thiaminase inhibitor (or perhaps high sulfur levels), and as yet an unidentified liver toxin
 2. Liver dysfunction after ingestion for a period of 35 to 40 days or longer
 3. Drought conditions and seed maturation seem to increase the toxicity of the plant. Saponins are thought to cause weight loss and a depression in feed intake
 4. Neurologic signs only associated with ingestion of green plant material
 B. Animals affected: Primarily cattle, sheep, and horses
 C. Mechanism of action: Clinical diseases associated with ingestion of this plant include photosensitization, polioencephalomalacia, toxic hepatitis, and toxic nephrosis
 D. Clinical signs
 1. Vary depending on which toxic principle predominates

2. In general, will see loose feces, depression, lacrimation, anorexia and weight loss, icterus, photosensitivity, bizarre behavior, nystagmus, head pressing, blindness, muscle tremors, opisthotonous, recumbency, and terminal convulsions

E. Pathologic lesions
1. Varies: Usually see jaundice, cerebral edema, fatty cirrhotic or enlarged liver, GI inflammation, pulmonary edema, and congestion
2. Hepatic necrosis and fibrosis, necrosis of proximal convoluted tubular epithelium, epidermal necrosis, and laminar cerebrocortical necrosis

F. Treatment: No specific treatment for liver dysfunction. Remove animals from source and keep out of the sunlight. Neurologic signs are not thiamine responsive

IX. *Trifolium hybridum* (alsike clover), *Trifolium pratense* (red clover)

A. Toxic principle and mechanism of action
1. Unknown - mold-mycotoxin or plant toxin? Disease associated with *Cymodothea trifolii,* the fungus responsible for *black blotch* or *sooty blotch*. Another hypothesis: *Capnocytophaga,* endophytic bacteria. Various glycosides and volatile oils have been isolated
2. Two conditions occur: Liver disease and trefoliosis (secondary photosensitivity). Contact dermatitis ("dew poisoning") of the feet and muzzle

B. Animals affected: So far, reported only in horses

C. Clinical signs
1. Onset within 7 to 30 days; variable depending on percentage in diet
2. Two clinical manifestations
a. Acute or nervous form: Alternating depression and excitement, head pressing, purposeless walking, incoordination, yawning, grinding teeth, and then rapid progression to paralysis, coma, and death
b. Chronic or cachectic form: Anorexia, loss of condition, weakness, sluggishness, dry harsh hair coat

D. Clinical pathology
1. Most consistent changes are elevations in GGT and ALP; less commonly affected are AST, ALT, and SDH
2. Bile acids, ammonia, and total bilirubin may be elevated; icterus is not a consistent change

E. Pathologic lesions
1. Liver can be normal, enlarged, or shrunken, with or without jaundice
2. Perilobular-centrilobular-periportal fibrosis, bile duct proliferation; parenchyma is almost unaffected; varying degrees of inflammation and necrosis; may occasionally see lipidosis and megalocytosis

F. Treatment: Symptomatic and supportive only

X. *Lantana* spp. (lantana)

A. Toxic principles and mechanism of action: Active principle, primarily lantadene A, is hepatoxic and will cause a secondary photosensitization. The entire plant is toxic, especially the fruits

B. Animals affected: All animals are susceptible. Most poisonings occur in humans, dogs, cattle, and sheep. The plant is not that palatable and is considered bitter. Horses appear to be relatively resistant

C. Clinical signs
1. Two clinical syndromes: Acute hepatotoxicity and photosensitivity
2. Vomiting, diarrhea, muscle weakness, collapse, and death
3. Secondary photosensitization common in livestock (build up of phylloerythrin)

D. Pathologic lesions: Photosensitization and hepatic necrosis (may see megalocytosis)

E. Treatment: No specific treatment

TOXICANTS AFFECTING THE NERVOUS SYSTEM

I. Strychnine

A. Source
1. Indole alkaloid derived from seeds of *Strychnosnux vomica* and *ignatii*.
2. Pesticide: Rodent control (below ground use; less than 0.5% sold over the counter in some states)
3. Sometimes dyed to warn of toxicity: green, red, pink
4. Seed-based baits are common; wheat, oats, sorghum, corn

B. Toxicity: All species susceptible; most commonly reported in dogs; also in livestock and other species. Secondary poisoning uncommon, but can occur

C. Mechanism of action
1. Rapid absorption from GI tract, metabolized by liver (benzoic acid)
2. Wide tissue distribution; does not accumulate in any one particular tissue
3. Competitive, reversible antagonism of inhibitory neurotransmitter glycine at postsynaptic sites in spinal cord and medulla. Result is unchecked reflex stimulation with the more powerful extensor muscles predominating; leads to severe, muscle rigidity and possible convulsions

D. Clinical signs
1. Onset is generally acute (15 to 30 minutes); dose dependent; looks like tetanus and lot of numerous other CNS toxicants
2. Clinical signs include anxiety; restlessness; increased respiratory rate; excessive salivation; violent, intermittent or continuous muscle tremors or convulsions (often spontaneous or stimuli induced; not specific)
3. Persistent rigid extension of all four limbs; jaw is clamped (sardonic grin)
4. Continuous or intermittent; gradually becomes more severe if dose high enough
5. Death from anoxia or hypoxia and hypercarbia; chest muscle and diaphragm spasms
6. Excessive muscle activity → hyperthermia and rhabdomyolysis (rare) → metabolic acidosis and acute renal failure is a possibility (unusual)

E. Clinical pathology and lesions: No specific clinical pathology or gross and microscopic lesions observed
F. Diagnosis
1. History of potential exposure: Free roaming dogs or malicious poisonings
2. Characteristic signs: Extreme extensor rigidity or convulsions
3. Chemical analysis
a. Stomach contents, lavage washings, vomitus, bait
b. Liver and bile, kidney, urine, serum; wide distribution so levels are often low (small amount of body burden [0.5%] is in blood at equilibrium)
G. Treatment
1. Aim is to prevent absorption, reverse hypoxia, hyperthermia and acidosis, minimize muscle spasms, and maintain adequate renal output. Quick elimination of the toxin will permit full recovery. Options depend on whether patient is symptomatic or asymptomatic
2. Control muscle spasms and convulsions
3. Decontamination: Emesis (be careful; do not want to initiate muscle activity), gastric lavage, AC, cathartic. Will shorten the course, lessen the severity, and improve prognosis
4. Airway management: Oxygen, fluids and diuretics
5. Quiet environment

II. Metaldehyde
A. Source
1. Acetaldehyde tetramer; slug and snail bait; pellets, meal, liquid
2. May be combined with methidocarb (acetylcholinesterase inhibitor); causes muscarinic signs
B. Toxicity: All species; most commonly in dogs
C. Mechanism of action. Acetaldehyde is liberated by gastric hydrolysis; mechanism unknown
D. Clinical signs
1. Onset can be few minutes (most common), up to 3 hours
2. Signs include premonition (incoordination, anxious, restless, salivation), muscle tremors (face, then body), sensitive to external stimuli, hyperthermia, tachycardia, tachypnea, hyperpnea, polypnea (increase rate and depth), ataxia, hyperesthesia (not as severe), vomition, mydriasis, nystagmus (cats), diarrhea, temporary blindness, convulsions, coma, death from respiratory failure. "Shake and bake syndrome"
E. Clinical pathology and lesions: Nonspecific; congestion of multiple organs. Liver and renal failure have been reported 2 to 3 days after intitial insult (rare)
F. Diagnosis: History (springtime); clinical signs (muscle tremors), lack of lesions, chemical analysis for metaldehyde, acetaldehyde (frozen stomach or intestinal contents)
G. Treatment
1. Aim is the same as for strychnine: Control muscle tremors and seizure activity, prevent absorption, reverse hypoxia, hyperthermia, and acidosis, and maintain adequate hydration and renal output
2. Options depend on whether patient is symptomatic or asymptomatic
3. Control seizure activity and muscle tremors
4. Decontamination: Emetics (careful), gastric lavage, AC? Cathartic: Depending on clinical presentation. Enemas will also be helpful
5. Airway management: Oxygen
6. Fluids (LRS or Normosol-R), bicarbonate to correct possible metabolic acidosis and maintain cardiovascular support
7. Control hyperthermia

III. Penitrem A
A. Source
1. Tremorgenic mycotoxins, produced by moldy foods (bread, cottage cheese, cream cheese, blue cheese, grain, walnuts, peanuts, almonds, garbage), and decaying organic material (compost pile, rotting leaves)
2. Produced by various species of *Penicillium*
B. Toxicity: All species appear to be susceptible; commonly recognized in dogs
C. Mechanism of action
1. Causes an increase in resting potential, endplate potential, and duration of depolarization
2. May also influence presynaptic transmitter release
3. Facilitates transmission of impulses across the motor endplate
4. May inhibit glycine, similar to strychnine
5. May inhibit γ-aminobutyric acid (GABA)
D. Clinical signs and clinical pathology
1. Onset is rapid
2. Signs include hypersalivation, panting, restlessness, ataxia, urination, vomition (50% will vomit), muscle tremors (may progress to tonic spasms or convulsions), hyperactivity to external stimuli, hyperthermia, hyperglycemia, signs of dehydration, rhabdomyolysis (rare), death
3. Clinical pathology changes: Nonspecific
E. Lesions: None
F. Diagnosis
1. History of potential exposure: Moldy foods, compost pile, garbage, digging holes; look at vomitus or lavage washings
2. Compatible clinical signs: Abrupt onset of muscle tremors
3. Chemical analysis: Stomach contents, bile, vomitus, gastric lavage. Serum: Both apparently excreted in bile (some in urine)
G. Treatment
1. No specific treatment: Symptomatic and supportive. Same as for strychnine and metaldehyde
2. Decontamination: Emesis, gastric lavage, AC and cathartic; dependent on presentation
3. Control muscle tremors and seizure activity: Methocarbamol
4. Maintain body temperature and respiration: Fluids and electrolytes

IV. Bromethalin
 A. Source: Rodenticide; available as a 0.01% to 2% tan or green pellet
 B. Toxicity: Most commonly seen in dogs and cats. Relay toxicosis has not been observed but may occur in the field. Excretion is slow: Half-life of 6 days in plasma
 C. Mechanism of action
 1. Uncoupler of oxidative phosphorylation in CNS mitochondria. Adenosine triphosphate (ATP) production is diminished, leading to accumulation of extracellular fluids
 2. Fluid buildup is manifested by fluid-filled vacuoles between the myelin sheaths. Results in increased pressure on nerve axons → decreased nerve conduction, paralysis, and death from respiratory paralysis (inadequate transmission from the respiratory center)
 D. Clinical signs
 1. Onset within 10 to 24 hours of ingestion
 2. Low doses (sublethal dose): Mild to severe depression, hindlimb paresis progressing to paralysis
 3. High doses: Severe muscle tremors, hyperexcitability, running fits, seizures (often precipitated by noise and light), hyperesthesia, vomiting, dyspnea, vocalization (cats)
 E. Clinical pathology: Nonspecific
 F. Lesions
 1. Mild cerebral edema; vacuolation and edema of white matter of cerebellum, cerebrum, brainstem, optic nerve, and spinal cord
 2. Electron microscopy: Vacuoles, edema, and splitting of the myelin sheaths
 3. Lesions may not be apparent in animals that die within 24 hours of ingestion
 G. Diagnosis: History, clinical signs (abrupt onset of CNS signs), histopathology, chemical analysis (liver, kidney, fat, brain) for bromethalin, desmethylbromethalin
 H. Treatment: Symptomatic and supportive; decontamination (emesis, gastric lavage, AC, cathartic), control seizures, maintain body temperature and respiration; adequate hydration status and electrolyte balance

V. Sodium monoflouroacetate (Compound 1080)
 A. Source
 1. Specific applications by licensed pesticide control operators; used for rodent and coyote control
 2. Highly toxic, colorless, odorless, water soluble compound
 B. Toxicity: All species; secondary or relay toxicosis is a major problem
 C. Mechanism of action
 1. Becomes toxic by "lethal synthesis"
 2. Replaces acetyl CoA in the Kreb's cycle and combines with oxaloacetate to form fluorocitrate. Fluorocitrate inhibits aconitase resulting in a shut down of the energy generating pathway. Also may see accumulation of citric and lactic acids
 3. Tissues heavily dependent on this pathway for ATP production are most affected: CNS, heart, GI tract
 D. Clinical signs
 1. Characteristic latent period: 0.5 to 2 hours after ingestion
 2. Dog: GI and nervous signs predominate: Anxiety, wild barking and running, repeated defecation and urination, tetanic seizures (increase in frequency and severity over time), death from respiratory failure and cardiac arrest
 3. Cat: Vocalization, excitation or depression, salivation, diarrhea, arrhythmia
 4. Ruminants, herbivores: Cardiac signs predominate: Arrhythmia, rapid weak pulse, ventricular fibrillation, ataxia, muscle tremors, collapse, terminal seizures
 E. Lesions: Nonspecific; empty GI tract and urinary bladder, liver and kidney congestion, rapid rigor mortis
 F. Diagnosis: History, clinical signs, lack of lesions; chemical analysis (urine, liver, kidney, stomach contents, bait)
 G. Treatment: Decontamination (emesis, gastric lavage, AC, cathartic) before clinical signs, control seizures; monacetin (source of acetate to compete with fluoroacetate); light sedation with pentobarbital + IV 0.9% saline + sodium bicarbonate

VI. 4-Methylimidazole (4-MI; bovine bonkers syndrome)
 A. Source: Specific soluble-reducing sugars (glucose, fructose) present in forages (sorghum, hybrid Sudan, cereal grains, brome and fescue grass, alfalfa, Bermuda hay) are converted to 4-MI following ammoniation; increases the feeding value by breaking down lignin
 B. Toxicity
 1. Adult cattle, nursing calves (active metabolite secreted in milk)
 2. Occurs when ammoniation levels are greater than 3% in susceptible feeds
 C. Clinical signs: Hyperexcitability, circling, wild running, mouth chomping, excessive salivation, impaired vision, seizures, death (uncommon). Onset is 24 hours to several weeks
 D. Diagnosis: History, clinical signs (bovine bonkers), chemical analysis of feed
 E. Treatment: Symptomatic; decontaminate (AC, cathartic)

VII. Methylxanthine (theobromine, caffeine, theophylline)
 A. Source
 1. Naturally occurring xanthine alkaloids (feed materials); synthetic pharmaceuticals
 2. Theobromine (chocolate), caffeine (coffee, teas, pharmaceutical), theophylline (pharmaceuticals)
 B. Toxicity
 1. All animals susceptible, even birds. Commonly observed in the dog
 2. Rapidly absorbed within GI tract. Excreted into bile (enterohepatic recirculation) and urine
 3. Metabolized by liver via *N*-demethylation and phase II conjugation
 C. Mechanism of action is not well understood
 1. Competitive antagonism of cellular adenosine receptors: Vasoconstriction, tachycardia, CNS stimulation

2. Inhibition of phosphodiesterase → increase in cyclic AMP → enhanced catecholamine release
3. Direct stimulation of catecholamine release
4. Increased entry of calcium into cells plus inhibition of calcium sequestration by sarcoplasmic reticulum → increase in muscle contractility

D. Clinical signs: CNS, bronchodilator, and diuretic effects (often waxing and waning): Vomiting, diarrhea, diuresis, restlessness, hyperactivity, tachycardia, tachypnea, ataxia, tremors, seizures, coma, death (cardiac arrhythmias and/or respiratory failure). May see death with no premonitory signs. Onset 1 to several hours

E. Diagnosis: Exposure, clinical signs, postmortem lesions; chemical analysis (plasma, serum urine, stomach contents, feces, bile, liver)

F. Treatment: Decontaminate (emesis, gastric lavage, AC), seizure control; monitor ECG (atropine for bradycardia; lidocaine, metoprolol, or propranolol for tachycardias), fluids to maintain hydration

VIII. Lead (Pb)

A. Source
1. Pb is ubiquitous and sources are many and varied. Common poisoning
2. Small animals: Paint (0 to 50% Pb): Dust, chips (renovation), used motor oil, leaded gasoline, drapery weights, sinkers, solder, foil from wine bottles, tile, linoleum, improperly glazed ceramic bowls
3. Large animals: Batteries, machinery grease (30% to 50% Pb), used motor oil, paint, soil-water-forage contamination from burn piles, mines and smelters, pesticides
4. Waterfowl, birds of prey: Lead shot
5. Pet psittacines: Paint, foil, toys, ceramics, jewelry

B. Toxicity
1. All species are potentially susceptible; young animals most sensitive
2. Commonly reported in cattle, young dogs, and waterfowl
3. Most toxicoses are result of acute exposure (all species except waterfowl)
4. Waterfowl and birds of prey: Exposures tend to be chronic
5. Common route of exposure is oral ingestion; 10% absorbed in adults (young: Greater than 50% absorption). Needs acidic environment
6. Reoccurrence of signs when bone (calcium) mobilization is occurring

C. Mechanism of action
1. Carried by erythrocytes ($T_{1/2} \sim 35$ days) to all tissues (responsible for signs) and redistributes to bone ($T_{1/2} \sim 5$ to 19 years); inert in bone. Crosses placenta and can enter milk. Excreted primarily in bile. Excreted in urine if chelation therapy is administered. Lead interferes with thiol (-SH) containing enzymes and may replace zinc in some enzymes
2. Cardiovascular system: Increases erythrocyte fragility and depresses bone marrow production (although anemia is usually not a significant finding except in birds, where it tends to be chronic exposure), interferes with delta aminolevulinic acid (ALA) dehydratase and ferrochelatase, enzymes involved in heme synthesis, inhibits function of nucleotidase. No hemolysis. Generally a chronic change
3. Neurologic system: Cerebral edema caused by increased vascular permeability; segmental demyelination of pharyngeal and recurrent laryngeal nerves (bovine, equine); GI stasis and wing paralysis common in birds
4. GI: Irritant

D. Clinical signs
1. Small animals: GI and nervous signs (especially in young) predominate: Rarely see acute death. Clinical signs include anorexia, depression, mild abdominal pain, vomiting, diarrhea, hyperexcitability, hysteria, intermittent seizures, blindness, PU/PD. Anorexia, depression, and vomiting predominate in cats
2. Ruminants: 90% exhibit neurologic signs, 60% exhibit GI signs: May see acute deaths, particularly in young animals. Hyperthermia is common. Signs include cortical blindness, circling, aimless wandering, rhythmic twitching, pharyngeal paralysis, tucked abdomen, constipation, diarrhea, ruminal atony, pharyngeal paralysis, excitement, convulsions
3. Horses: Similar to ruminants. Signs include anorexia, colic, muscle weakness, seizures, laryngeal or pharyngeal paralysis, depression
4. Waterfowl and birds: Often nonspecific because disease is often chronic in nature. Often succumb to infectious processes. Signs include depression, weakness, ataxia, diarrhea, green droppings, PU, proventricular impaction, anorexia, wing paralysis, clenched talons, blindness, circling, convulsions, weight loss

E. Clinical pathology
1. Nucleated red blood cells (RBCs) without significant anemia (abnormal bone marrow release of nucleated cells due to effect on spaces of the sinusoidal barrier). Basophilic stippling (inhibition of pyrimidine-S-nucleotidase): Not consistent in dogs or cats; more commonly seen with chronic exposures
2. Radiographs: Radiopaque material (reticulum, GI tract), metaphyseal sclerosis
3. Birds: Hypochromic, regenerative anemia

F. Lesions: Often absent or nonspecific
1. Gross: Moderate brain swelling, mild gastritis, and enteritis, GI erosions, pale liver, pale muscle, distended gallbladder
2. Microscopic: Laminar cortical necrosis, intranuclear inclusion bodies (kidney, brain, will see only in chronic exposures or massive acute exposures); centrilobular degeneration, proximal tubule degeneration and necrosis

G. Diagnosis: History, clinical signs, radiographs, histopathology (lesions in brain); lead analysis of whole blood, liver, and kidney

H. Treatment
1. Decontaminate: Emetics, lavage, cathartics; Mg or $NaSO_4$ binds Pb and precipitates out as $PbSO_4$

2. Chelation: Exchanges calcium for lead in blood, tissues, and bone and enhances urinary excretion; succimer (Chemet), CaEDTA, dimercaprol (British Anti-Lewisite, bronchoalveolar lavage in oil), penicillamine (Cuprimine)
3. Thiamine hydrochloride (vitamin B_1)
4. Seizure control
5. Zinc supplementation
6. Recheck blood lead in 10 to 14 days

IX. Nonprotein nitrogen (urea)
A. Source
1. Urea, biuret, ammonium salts (diammonium phosphate, ammonium polyphosphate, ammonium sulfate, monoammonium phosphate) provide inexpensive source of non-protein nitrogen (NPN)
2. Present in feed supplements for mixing, range blocks, range cubes, liquids (alcohol, molasses)
3. Fertilizers: Can contain up to 44% urea

B. Toxicity
1. Occurs when animals ingest excessive amounts that result in release of excessive amounts of ammonia (NH_3)
2. Ruminants are more susceptible to urea because of the hydrolysis of urea to ammonia by rumen microorganisms. Ruminants should be placed on NPN rations gradually (7 to 10 days) to allow microbes to adapt
3. Ruminants should have a ready supply of carbohydrate

C. Mechanism of action
1. NPN compounds furnish ammonia, which rumen microorganisms use along with carbohydrates to synthesize amino acids and proteins. Toxicosis occurs when NPN hydrolysis yields ammonia levels that far exceed what can be used by rumen microorganisms or when soluble carbohydrate levels are low
2. When the rumen flora fail to utilize excess ammonia, the ammonia dissolves in the fluids, takes on protons to form ammonium (NH_4^+). The pH of the rumen rises (fewer hydrogen ions are available), the ammonium ions are no longer formed and the concentration of ammonia (NH_3) increases
3. Ammonia penetrates the rumen wall and blood levels of ammonia increase. Ammonia becomes incorporated into the urea cycle and excreted as urea in the urine. Toxicosis results when this system is overwhelmed. Get a rumen alkalosis with a circulatory metabolic acidosis, hyperkalemia-induced cardiac failure

D. Clinical signs
1. Onset: At 0.5 to 4 hours, typically someone sees large number of affected animals shortly after the introduction of "new feed"
2. Clinical signs include abdominal pain, muscle tremors, salivation, incoordination, weakness, dyspnea, bloat, violent struggling, convulsions, death within 4 hours

E. Clinical Pathology Lesions: Nonspecific; bloat, mild pulmonary edema, congestion of visceral organs

F. Diagnosis
1. History of feeding NPN - recent change in diet
2. Clinical signs - usually affects more than one animal in a group
3. Chemical analysis: All samples need to be frozen and collected soon after death. Rumen pH: Greater than 8.0. Ammonia analysis: Serum, whole blood, vitreous humor, cerebrospinal fluid (CSF), abomasal contents; be careful with interpretation if significant delay after death. Urea (NPN) analysis: Feed

G. Treatment: Most effective within 20 minutes of onset of clinical signs; give cold water, 5% acetic acid (vinegar); provide supportive therapy

X. Organophosphorous and carbamate pesticides (acetylcholinesterase inhibitors)
A. Source
1. Insecticides, anthelminthics, chemical warfare agents, drugs
2. In people, about 50% are agriculture related. Of nonagriculture half, home and garden applications constitute a third, such as negligence in reading labels, lack of personal protection, product overuse, and inadequate ventilation

B. Toxicity
1. Lethal doses are variable and range from nontoxic to extremely toxic
2. Most toxicoses result from accidental access or management negligence and inappropriate use of sprays, dips, and pour-ons
3. Direct toxicosis from aerial spraying is uncommon; drift can be a problem
4. Most inactivated by the mixed function oxidase (MFO) and excreted in urine and bile; generally no residue problem except for the heavily chlorinated ones

C. Mechanism of action
1. Inhibition of acetylcholinesterase activity leads to accumulation of acetylcholine at sympathetic and parasympathetic preganglionic junctions, all parasympathetic postganglionic junctions and few sympathetic postganglionic junctions (muscarinic), motor nerves to skeletal muscles (nicotinic), some neurons within CNS (can see excitation or depression)
2. Insecticides competitively bind to the active esteratic site of enzyme. Enzyme becomes "phosphorylated" (irreversible) or "carbamylated" (reversible), making it inactive. Loss of an alkyl group strengthens the existing covalent bond and is referred to as *aging*. Once aging occurs, use of oximes is *not* effective.
3. Buildup of acetylcholine results in overstimulation of receptors

D. Clinical signs
1. Usually rapid following exposure (route, form, and dose are limiting factors)
2. Muscarinic: Smooth muscle, exocrine, heart (SLUD, DUMDBELS). Clinical signs include salivation, anorexia, vomiting, diarrhea,

lacrimation, miosis, mydriasis, dyspnea, micturition, bradycardia, or tachycardia
3. Nicotinic: Skeletal muscle, autonomic ganglia. Clinical signs include twitching of facial muscles, eyelids, tongue, and general musculature; weakness, paralysis, respiratory paralysis, death
4. CNS signs include excitation (sometimes depression) and seizures (most common in massive, large, fatal exposures)
5. Horse: Abdominal pain, diarrhea, dehydration; salivation is less common
6. Dogs and cats: Changes compatible with a pancreatitis; death from respiratory failure (increased respiratory secretions, bronchiolar constriction, depression of the respiratory center, and paralysis of respiratory muscles)

E. Clinical pathology, gross and microscopic lesions: Nonspecific; evidence of excessive salivation, bronchial secretion and pulmonary edema, hemorrhages within GI tract serosa and mucosa
F. Diagnosis
1. History of potential exposure; known use, summer or fall spraying, malicious use
2. Appropriate clinical signs: Muscarinic, nicotinic, possible CNS
3. Acetylcholinesterase activity: Good screening tool
4. Chemical residue analysis: Stomach or rumen contents; liver, kidney, suspect source; parent compound or metabolites

G. Treatment: Decontamination (emesis, bathe, AC, cathartic), atropine sulfate, oximes (careful use with carbamates), supportive (maintenance of patent airway and oxygen, control metabolic acidosis, control muscle tremors)

XI. Pyrethrins and pyrethroids
A. Source
1. Pyrethrum and pyrethrins are natural insecticides produced by exotic *Chrysanthemum* flowers. Pyrethroids are synthetic compounds
2. Flea and tick repellents and insecticides. Used in agriculture, commercial use, residential use, animal health care products. Many different forms, such as aerosols, sprays, dusts, tags, dips, shampoos, foggers

B. Toxicity
1. Varies with compound and route of exposure: Low toxicity to mammals
2. Products containing more than 1% not recommended for cats. Some cats also appear to respond adversely to "normal" dose exposures
3. Tissue residues low; rapid breakdown in GI tract (hydrolysis or ester linkage) and rapid hydrolysis or oxidation by liver and plasma esterases and oxidases. Environmental residues low
4. Most reports in dogs and cats

C. Mechanism of action
1. Pyrethrins and type I pyrethroids: Prolong Na^+ conductance, suppress K^+ conduction; → increased depolarizing after potential → repetitive nerve discharges or inhibits calcium-ATPase and calcium magnesium-ATPase
2. Type II pyrethroids: Depolarization of nerve membranes without repetitive discharges; interfere with binding of GABA and glutamic acid at receptor sites; inhibits calcium-ATPase and calcium magnesium-ATPase

D. Clinical signs
1. Onset varies; generally within few hours
2. In livestock and companion animals: Excessive salivation (effect on sensory nerve fibers), depression, muscle tremors, seizures, ataxia, vomiting, weakness, dyspnea, diarrhea, hyperesthesia (ear flicking, paw shaking, repeated contractions of superficial cutaneous muscles), recumbency, blindness

E. Clinical pathology, gross and histologic lesions: Nonspecific
F. Diagnosis: Exposure, clinical signs, chemical residue (skin, liver, GI contents)
G. Treatment: Decontamination (bathe, emetics, AC, cathartic), control tremors and seizures (diazepam, methocarbamol), maintain normal body temperature (prevent rebound hypothermia), nutrition support (tuna, milk to help rinse out mouth)

XII. Chlorinated hydrocarbons
A. Source is pesticides. Current use for many is limited for both agricultural, house or home, and veterinary use
B. Toxicity: Toxic to all mammalian systems; high lipid solubility and stability lead to biological magnification (move up the food chain) + environmental contamination
C. Mechanism of action
1. Slow down the turning off of Na^+ influx; inhibit turning on of K^+ outflux → partially depolarizes nerve membrane → diffuse nervous stimulation
2. Competitive inhibition of binding of GABA at receptor site

D. Clinical signs
1. Onset varies from a few minutes to several hours
2. Clinical signs include apprehension, anxiousness; salivation; premonition; hyperexcitability; muscle tremors of the head, neck, and body; seizures (continuous or intermittent); excessive response to external stimuli
3. Death usually follows within 20 to 60 minutes after onset of signs if left untreated

E. Lesions: Nonspecific; with chronic exposures, may see hepatocellular and renal tubular degeneration and necrosis
F. Diagnosis: History, clinical signs (CNS stimulation), chemical analysis (brain, liver, fat, GI contents, source material, milk, serum)
G. Treatment: Decontamination (for acute exposures, bathe, emetics, AC, cathartic), sedation, supportive (maintain fluid and electrolyte balance)

XIII. Cyanobacteria (*Anabaena, Aphanizomenon, Oscillatoria* spp.)
A. Source
1. *Anabaena flos-aquae* or *spiroides, Aphanizomenon flos-aquae, Oscillatoria* spp., stagnant,

eutrophic ponds, lakes, watering holes. Calm weather
2. Require phosphate, nitrate, sulfate for optimum growth. Animals exposed when wind concentrates toxic amount of bloom along shoreline

B. Toxicity and mechanism of action
1. Anatoxin-a: Potent, fast-acting; mimics acetylcholine. Bind to acetylcholine receptor, triggers contraction; cannot be degraded by acetylcholinesterase. Continue to act; muscle cells exhaust from contracting and stop operating
2. Saxitoxin and neosaxitoxin: Sodium channel blockers prevent sodium from passing into neurons; impulse does not get propagated and muscle cells receive no stimulation
3. Small amount of microcystin may be produced

C. Clinical signs: Rapid onset; muscle rigidity, tremors or seizures, paralysis, early apprehension, anxiety, salivation, vomiting, diarrhea, death from respiratory paralysis

D. Clinical pathology, lesions: Nonspecific

E. Diagnosis: Algae-associated discoloration of hair, skin, GI tract; clinical signs, appropriate weather conditions, algae identification

F. Treatment: Decontaminate, maintain adequate respiration, control seizure activity, atropine

XIV. Perennial ryegrass staggers (others include dallisgrass staggers, *Paspalum* staggers, Bermuda grass staggers, *Phalaris* staggers, annual ryegrass staggers)

A. Source
1. Toxic endophyte, *Acremonium lolii (Neotyphodium lolii)*, found on lower leaf sheath of perennial rye grass (*Lolium perenne*). Other grasses may be involved. Also found in seeds
2. Occurs late summer and fall when grass stubble is 3 to 5 cm tall. Also hay
3. Symbiotic relationship: Fungus growing within a plant

B. Toxicity and mechanism of action
1. Reported in cattle, sheep, horses, deer, elk. Morbidity very high; mortality very low if moved to safe pastures
2. Under certain conditions, fungus produces a group of toxins called: lolitrems (indole-based alkaloids). Some strains may also produce ergovaline
3. Pathologic lesions rare; effect is thought to be biochemical (Purkinje cell lesions)

C. Clinical signs: Fine muscle tremors of head and neck; uncoordinated jerky gait (forelimbs first,

3. Cattle: Weakness, aggressiveness, belligerent behavior, secondary bloat (sucking in air), incoordination, bellowing, tremors, ear twitching, blindness, seizures, diarrhea, vomiting, regurgitation, anorexia, thirst
4. Poultry: Thirst, dyspnea, wet droppings, paralysis of hindlimbs

E. Lesions
1. Swine. Gross: Cerebral edema and malacia. Histology: First 48 hours; see eosinophilic meningoencephalitis; after 3 to 4 days, eosinophilic cuffs no longer there and enlarged perivascular spaces can be seen
2. Cattle, Canine. Gross: Systemic congestion, cerebral edema, malacia, systemic edema. Histology: Nonspecific
3. Poultry: Systemic edema and urate nephrosis

F. Diagnosis: History (herd problem in livestock), clinical signs, lesions, chemical analysis (serum Na greater than 160 mEq/L, CSF Na concentrations)

G. Treatment: Remove salt source; slow rehydration IV. Give small amounts of water

XIX. Amitraz

A. Source
1. Formamidine pesticide, which controls mites and ticks. Often mixed with xylene
2. Dogs intoxicated by eating acaricide collars
3. Mitaban (19.9% amitraz): Topical control of generalized demodecosis

B. Toxicity and mechanism of action
1. Absorbed both orally and parenterally; peak blood levels in 2 to 6 hours. Wide distribution; metabolized to 4-amino-3-methylbenzoic acid; excreted in urine
2. May see transient depression at recommended levels (2 to 6 hours after exposure, last 24 to 72 hours). Amitraz not recommended in animals that weigh less than 5 kg
3. α2-adrenergic agonist and weak monoamine oxidase inhibitor; inhibits insulin release. CNS and cardiovascular system are prime targets; cardiovascular collapse and respiratory depression

C. Signs include hypotension, bradycardia, ataxia, depression, disorientation, vomiting, anorexia, mydriasis, hypothermia, PU, GI stasis or diarrhea, vocalization, seizures

D. Diagnosis: Exposure, clinical signs, hyperglycemia, lack of lesions. Chemical confirmation: liver, kidney, skin, brain, lung, fat, spleen

E. Treatment: Decontamination (bathe, emetics, AC, cathartic), fluid therapy (IV or subcutaneous; 0.9% saline or LRS); yohimbine (reverses bradycardia, hypotension, sedation, GI hypomotility), atipamezole

XX. *Dicentra* spp. (bleedingheart, dutchman's breeches)

A. Toxic principles: Isoquinoline-like alkaloids (e.g., aporphine, protoberberine, protopine) present in all parts of the plant, especially the leaves and bulbs. Infrequent cause of toxicosis due to lack of dense stands

B. Animals affected
1. All animals susceptible, primarily cattle and sheep
2. Requires 2% to 4% body weight of plant material to induce toxicosis. Unpalatable
3. *Delphinium* occurs in similar locations with similar symptoms

C. Mechanism of action: Exact mechanism of action is unknown

D. Clinical Signs
1. Fairly rapid onset of excessive salivation, muscle tremors, vomiting, abdominal pain, prostration, and opisthotonous
2. May rarely progress to convulsions and death. Recovery from poisoning is usually rapid following removal of the plant and supportive care

E. Pathologic lesions: Nonspecific

F. Treatment: Symptomatic and supportive care may include AC, saline cathartic, fluids. Often recover in a few hours without treatment

XXI. *Cicuta* spp. (water hemlock)

A. Toxic principles
1. Cicutoxin and cicutol (unsaturated alcohol), present in thick yellow resin with a carrot-like odor; found in root, base of stem, and early young shoots. Toxin goes up the stem and can concentrate in the seed
2. Toxicity of the above-ground plant decreases as plant matures. One large root (10 to 12 oz) is enough to kill adult cattle, 2 oz of root or young shoots is enough to kill a sheep, and 15 oz of root is enough to kill a horse
3. Toxin is also present in the seeds; cattle have been poisoned by eating the seeds while ingesting the flower heads or contaminated water

B. Animals affected. All species; most common in sheep and cattle. Usually in early spring, when young shoots are coming up and roots are easily uprooted. Toxicoses in cattle drinking water from puddles where plant material has been trampled

C. Mechanism of action: Alters ion permeability and thereby irritates the nerve and muscle cells

D. Clinical signs: Muscle twitching, tachypnea, excessive salivation, violent convulsions, and death from respiratory paralysis within 45 to 60 minutes of ingestion. Rapid onset, within 15 to 30 min after ingestion

E. Pathologic lesions: Nonspecific. Young shoots and pieces of root almost always visualized in the rumen

F. Treatment
1. Treatment is usually too late. If possible, AC, saline cathartic, rumenotomy, control seizures and muscle spasms, assist respiration
2. If animal is still alive after 2 hours post-ingestion, most likely will survive. Cicutoxin can be isolated from rumen-stomach contents but difficult from serum and tissues (short half-life)

XXII. *Centaurea solstitialis* (yellow starthistle) and *Centaurea-Acroptilon repens* (Russian knapweed)
- A. Toxic principles, mechanism of action
 1. Toxin may be sesquiterpene lactones (repin, chlororepdiolide, acroptilin from *C. repens*, solstitialin A 13-acetate and cynaropicrin from *C. solstitialis*) or a pyrone compound, concentrated in the aerial portions of the plant
 2. Most toxicoses are associated with ingestion of the young plant and flowers, although the dried plant is still considered by some to be as toxic
 3. Horses may acquire a taste for the plant. Toxicosis occurs over a period of 30 to 90 days, eating huge amounts on a daily basis
 4. Interruption of the dopaminergic nigrostriatal pathway; loss of coordinating and inhibiting impulses from the cerebral cortex; impairment of cranial nerves V, VII, IX, and XII. Local reflexes and sensations remain intact
 5. Early clinical signs due to increased dopamine secretions, later followed by dopamine deficiency
 6. Cattle may graze yellow starthistle in early spring; nutritional value is low, similar to cured timothy hay
 7. As the plant matures, it becomes unpalatable. Cumulative storage of toxins rather than cumulative effect or damage; prolonged feeding periods interrupted at 1- or 2-week intervals do not result in disease; not sure how reliable this is
 8. Sixty to 100% body weight needs to be consumed to elicit a clinical effect
 9. Lesions develop quickly and completely; progressive changes are not apparent histologically
- B. Animals affected: Equine only; condition is called *nigropallidal encephalomalacia or chewing disease*
- C. Clinical signs
 1. Onset of signs is often sudden: Involuntary lip twitching, upper lip pulled over the teeth (hypertonicity of the lips, face, and tongue), lower lip often drooping, involuntary tongue and chewing movements, yawning, head tossing
 2. Animals are unable to drink normally or swallow food; inability to hold and masticate food and move the bolus back to the pharynx
 3. Death is often a result of starvation
 4. Less commonly observed: Ataxia, hypermetria, muscle tremors, depression, dyspnea
- D. Pathologic lesions: Bilateral, symmetrical, nonprogressive, focal necrosis and malacia of the anterior globus pallidus of the cerebrum and substantia nigra of the mesencephalon
- E. Treatment: Prognosis is grave, and once clinical signs appear, recovery is not possible

XXIII. *Astragalus* spp. (milk vetches, poison vetches, locoweeds), *Oxytropis* spp. (point locoweeds, point vetches, crazyweed), *Swainsona salsula*
- A. Toxic principles
 1. *Miserotoxin* (glycoside of 3-nitropropanol) and other nitro-containing glycosides (cibarian, hiptagin, karakin): Concentration is highest during pod formation. Plants are nontoxic when dry
 2. Indolizidine alkaloids swainsonine and swainsonine N-oxide. Plants are toxic when dried. All parts of the plant are considered toxic, with the highest concentration of alkaloids present in pods and seeds
 3. Selenium accumulators
 4. Some species of *Oxytropis* have been associated with high-altitude disease (right-sided heart failure)
 5. Some species are not toxic and are good-quality forages. Animals appear to become habituated to locoweeds, selectively seeking out the plants when grazing, possibly because of their palatability. Production of toxins are linked to the presence of an endophyte (*Embellisia* spp.), particularly swainsonine
- B. Mechanism of action
 1. Miserotoxin → 3-nitro-1-propanol → 3-nitro-propionic acid in the rumen: Effect is primarily on the respiratory system and CNS. 3-Nitro-propionic acid causes vasodilation and hypotension. Inhibition of succinate dehydrogenase → cellular respiration. It further breaks down into inorganic nitrite and a 3-carbon side chain. The nitrite complexes with hemoglobin to form methemoglobin (moderate increases only, not the primary cause of death)
 2. Swainsonine and swainsonine N-oxide: Inhibit the enzymes α-mannosidase and Golgi mannosidase II, which leads to an accumulation of mannose-rich oligosaccharides in cytoplasmic vacuoles and lysosomes of neurons, renal tubules, and hepatocytes. Vacuoles first appear in kidney tubules after 4 days of exposure. By day 32, almost all tissues show vacuolation except skeletal and cardiac muscle. Vacuolation of the glial cells, the axons, and the Purkinje cells of cerebellum and cerebral cortex account for neurologic signs (as well as impairing function of liver, digestive organs, placenta, and testicles). Abortions caused by interference with the passage of nutrients, vacuolation of the corpus luteum affecting the production of progesterone, vacuolation interfering with placentation, or direct effects on the fetus. In early stages, vacuolation is reversible, but permanent cellular damage occurs as animals eat locoweeds for long periods. Similar to generalized lysosomal storage disease. Neuro-lesions difficult to reverse
 3. Selenium accumulation; obligate selenium accumulators or indicator plants

C. Animals affected
 1. Primarily cattle, sheep, and horses; goats can be affected as well
 2. Amount of plant necessary to induce toxicosis varies with species of plant, time of year, and species of animal affected. As the amount of plant ingested increases, the worse the clinical signs become and the higher the rate of abortions and congenital malformations

D. Clinical signs
 1. Miserotoxin-containing plants
 a. Cattle most susceptible: General body weakness, knuckling of the fetlocks, and ataxia (due to demyelination of the posterior spinal cord), respiratory tract distress (dyspnea, persistent cough), cyanotic mucous membranes, and sudden death in 4 to 20 hours
 b. The clicking of the dew claws has led to the condition being called "cracker heels"
 2. Locoism
 a. Horses most sensitive. Neurologic signs usually develop after animals have consumed large amounts for 4 to 6 weeks or longer. See progressive sensory and motor derangements
 b. Initially, see incoordination and locomotor ataxia, visual impairment (from decreased lacrimation and vacuolation of retinal cells), depression, unpredictable behavior (hyperexcitability or depression), emaciation (from impaired function of liver, pancreas, thyroid, and parathyroid glands), rough and dull hair coat, and eventual death
 c. Abortions in sheep, horses, and cattle as well as congenital malformations (contracted tendons, lateral rotation of the forelimbs, flexion deformities of the carpus metacarpophalangeal, metatarsophalangeal, or distal interphalangeal joints, anterior flexure and looseness of the tarsal joints, aplasia of the lower jaw) in sheep, cattle, horses, and goats. The time of fetal insult is nonspecific; usually less than 120 days' gestation in cattle and horses; anytime in sheep (greatest after day 25). Decreased libido and reproductive failure have been reported in poisoned rams as a result of vacuolation of the testicular cells as well as suppressed sexual activity of bulls and suppressed estrous in cows. Locoweed poisoning has also been associated with an increased incidence of right-sided heart failure in cattle grazing *Oxytropis sericea* at high altitudes. The alkaloids are also passed in the milk of cows and may account for the unthriftiness of calves (weight loss, decreased T3,T4) suckling cows that are grazing locoweed. Experimental feeding of locoweed suppresses T-lymphocyte function and liver enzymes (serum AST and ALP) are often elevated because of liver damage
 3. Selenium toxicosis
 4. High-altitude disease: Brisket disease with head and facial edema, hydrothorax, hydropericardiaum, ascites, dyspnea, trembling, death

E. Lesions
 1. Miserotoxin-containing plants: Pulmonary emphysema and pneumonia, interlobular edema, fibrosis, and wällerian degeneration of the posterior spinal cord and peripheral nerves
 2. Swainsonine-containing plants: Edematous vacuolations of many cell types, such as neurons, renal cortical tubular cells, hepatocytes, pancreas, and placenta. Also retinal damage and vacuolar degeneration of lacrimal gland. Abortions, small weak or malformed young, and impaired spermatogenesis in rams. Early lesions may be reversible, especially when exposures are brief. Serum mannosidase levels, elevations in AST, LDH, ALP; low albumin (urinary glomerular proteinuria) and low T_3 and T_4 are nonspecific indicators of toxicosis. Can test for serum swainsonine (short half-life, 20 hours) and α-mannosidase activity (useful within 6 days only). Cytoplasmic vacuoles of peripheral blood lymphocytes
 3. Selenium accumulation plants
 4. High-altitude disease: Edema, heart failure lesions

F. Treatment: Remove animals from the source of plant exposure. Depending on the extent of the disease, recovery is variable. There is no specific treatment; symptomatic and supportive. Thiamine has been used with variable results in treating locoed animals

XXIV. *Aesculus glabra* (Ohio buckeye, horse chestnut)
 A. Toxic principles
 1. Aesculin, found in the nuts, bark, leaves, and flowers
 2. Toxicoses have been reported in cattle and horses, with toxic dose $\approx$ 0.5% to 1% of animal's body weight
 B. Clinical signs: Incoordination, ataxia, hypermetria, weakness and falling. Gastroenteritis with fluid and electrolyte loss have also been reported
 C. Lesions: Nonspecific; hepatic and renal congestion
 D. Treatment: Detoxification and supportive care

XXV. *Ipomea* (morning glory)
 A. Family: Convolvulaceae
 B. Description and habitat: Heart-shaped leaves and showy, trumpet-shaped, white-blue-violet flowers. Grows as a vine and is a common ornamental plant
 C. Toxic principles: Lysergic acid derivatives (ergosine and ergosinine) found in the seeds
 D. Clinical signs: Nausea, mydriasis, hallucinations, diarrhea, and hypotension. May see bizarre behavior, barking and disorientation
 E. Treatment: Decontamination and supportive care. Tranquilizers or sedatives

XXVI. *Cannabis sativa* (marijuana, hemp, pot, grass, hashish, Mary Jane, sensemilla)
 A. Toxic principles
 1. A series of related tetrahydrocannabinoids, the most active being δ-9-tetrahydrocannabinol (THC)

2. Entire plant is toxic, especially after it has been dried or aged, heated, or smoked. Toxicity of the plant varies with variety, sex, location grown, and stage of growth. Plant has very bitter taste
3. An animal can become intoxicated by having someone blow smoke directly into its nostrils

B. Mechanism of action: THC causes marked CNS depression and derangement
C. Animals affected: Dogs commonly affected (rarely cats)
D. Clinical signs: Acute onset of ataxia, depression, "glassy"-eyed, vomiting, mydriasis, nystagmus, hypothermia, inappropriate urination, and sometimes coma. Other signs include tachycardia or bradycardia, hyperexcitability, tremors, and salivation. Fatalities unusual. Depression may persist for 18 to 36 hours. Allergic inhalant dermatitis has been reported in dogs
E. Treatment: Decontaminate (emesis, gastric lavage, AC, saline cathartic); symptomatic and supportive. Recovery may be slow

XXVII. *Datura stramonium* (thorn apple, Jimson weed, Jamestown weed)
A. Toxic principles
1. Atropine, hyoscyamine (isomer of atropine), and scopalamine (an epoxidized hyoscyamine)
2. Unpalatable; poisoning occurs only when adequate feed is unavailable
3. Plant may become incorporated into hay, and seeds may become incorporated into feed grains. Entire plant is toxic; however, highest concentration of toxins are present in the seed

B. Mechanism of action, animals affected, clinical signs, treatment
C. Animals affected: All species susceptible. Signs may include trembling and excitation, colic, dilated pupils, dry tacky mucous membranes, tachycardia, blurred vision and decreased intestinal motility. Treatment is symptomatic and supportive in nature; physostigmine might be helpful.

XXVIII. *Lupinus* spp. (lupine, bluebonnet)
A. Toxic principles
1. More than a dozen quinolizidine alkaloids (lupoine, sparteine, lupinine) have been isolated; best known is anagyrine (causes deformations). Some piperidine alkaloids (ammondendrine) also can cause deformations
2. The alkaloids are not lost upon drying. Toxicity of the plant varies greatly; depends on species and variety of plant, time of year, species of animal affected
3. Many species have been shown to be acceptable forage under certain range conditions. However, all lupines should be considered suspicious
4. Most intoxications occur when an animal ingests a large amount in a relatively short period
5. Toxins can pass into milk. Anagyrine levels decrease during the pod stage

B. Mechanism of action
1. The alkaloids have a nicotinic-like effect. Nicotine itself mimics acetylcholine at sympathetic and parasympathetic ganglia, neuromuscular junctions of skeletal muscle, and at some synapses of the CNS
2. Low doses cause depolarization and stimulation of receptors similar to acetylcholine. Higher doses cause stimulation followed by blockade at autonomic ganglia and myoneural junctions of skeletal muscle. Stimulation of sympathetic ganglion and adrenal medulla causes a release of catecholamines. Death is due to respiratory failure from neuromuscular blockade

C. Animals affected
1. Sheep, horses, and cattle can be affected
2. Species susceptibility most likely result of range management practices

D. Clinical signs
1. Onset within 1 to 24 hours; dyspnea, depression, salivation, ataxia, spasms, head-pressing tremors, seizures, coma, death within one to several days after ingestion
2. Lupine ingestion is a cause of "crooked calf disease"; cows exposed between days 30 and 100 of gestation give birth to live calves with misaligned joints, arthrogryposis, and cleft palates. Forelimbs primarily affected, along with neck and vertebrae. Anagyrine is thought to act as an anesthetic to the developing fetus, restricting fetal movement and thereby causing the bone deformations (uterus shrinks down and conforms to shape of fetus). Piperidine alkaloid (ammodendrine) in *L. formosus* causes deformations in cows, sheep, and goats
3. Abortions have also been known to occur at any stage of gestation

E. Pathologic lesions: No specific lesions; can test for alkaloids in GI contents
F. Treatment: Symptomatic and supportive only

XXIX. *Conium maculatum* (poison hemlock)
A. Toxic principles
1. Piperidine alkaloids with nicotinic effects (e.g., β coniceine, conhydrinone, coniine, *N*-methyl coniine, conhydrine, pseudoconhydrine, and γa-coniceine). Main active alkaloids are the coniceine isomers
2. Concentrations of the different alkaloids vary; all parts of the plant are toxic, and toxicity increases as the plant matures
3. γ-coniceine can cause deformations and is possibly a teratogen. Most alkaloids are volatile, so some toxicity is lost upon drying. There have been cases of toxicosis in cattle eating contaminated hay. Boiling does not destroy the toxins

B. Mechanism of action
1. Nicotine-like effects: Refer to *Lupinus*. Alkaloids stimulate, then paralyse the nicotinic receptors

2. Large doses act as a depressant and cause neuromuscular block as well as low blood pressure and heart rate

C. Animals affected: All animals susceptible, including humans. Most commonly observed in cattle. Sheep and horses are relatively resistant

D. Clinical signs
1. Acute onset (within 1 to 2 hours) of muscle tremors, ataxia, muscle weakness, excessive salivation and lacrimation, mydriasis, frequent urination and defecation. Progresses to depression, recumbency, abdominal pain, respiratory distress, and death from respiratory arrest within 2 to 3 hours. May be able to detect a "mousy" odor to the urine and expired air
2. Teratogenic, deformations: Cows exposed between days 40 and 70 and sows between days 30 and 61 of gestation will give birth to calves and piglets with skeletal deformations, such as arthrogryposis ("crooked calf syndrome"), cleft palate, microphthalmia, and spinal column deformities. Malformations and deformations also seen in goats and sheep

E. Pathologic lesions: Nonspecific; may detect "mousy" odor to rumen contents. Alkaloids detected in stomach or rumen contents and urine

F. Treatment: Decontaminate (AC, saline cathartic), supportive. Use atropine with caution, and only if GI signs are severe. Provide respiratory support

XXX. *Delphinium* spp. (larkspur, poison weed, staggerweed)

A. Toxic principles
1. Polycyclic diterpene alkaloids; methylcaconitine and 14-deacetylmedicauline responsible for toxicity
2. Alkaloid content varies; tall larkspurs have greater alkaloid concentrations than low larkspurs; low during drought situations. Succulent preblooming and blooming plants contain highest alkaloid content (most toxicoses occur in spring and fall) for tall larkspurs and are most palatable to cattle. Toxic alkaloid concentration decreases as the plant matures. Low larkspur's alkaloid content stays fairly constant through the shorter growth season. These alkaloids are beneficial to the larkspur because they deter some insects
3. One of the major causes of range cattle poisoning in the western states. For low larkspur, cold wet springs cause early summer death losses to increase

B. Mechanism of action: Binds to acetylcholine receptors at the neuromuscular junction, causing muscle fatigue and eventual paralysis Death is from respiratory paralysis

C. Animals affected
1. Cattle are most susceptible, followed by goats and horses
2. Sheep are able to tolerate up to four times as much alkaloid
3. Larkspur is considered to be palatable (maybe because of its high Ca content)

D. Clinical signs: Depends on alkaloid content and rate of consumption (about 5 to 7 hours)
1. Common manifestation: sudden death
2. Initial uneasiness, increased excitability, stiffness, base-wide stance. Collapse of front legs progressing to sternal or lateral recumbency. Common to see involuntary muscle twitching, abdominal pain, regurgitation, constipation, and bloat. Death is from respiratory failure, usually within 3 or 4 hours within onset of clinical signs

E. Pathologic lesions. No specific findings; nonspecific findings include venous congestion, GI inflammation, bloat, inhalation pneumonia. Examination of rumen contents for larkspur is best means of confirming larkspur intoxication. Identification of alkaloid from rumen contents

F. Treatment: Often not successful. Stress exacerbates clinical signs. Give AC, cathartic, physostigmine

XXXI. *Equisetum* spp. (horsetail, scouring rush, marestail, Indian toothbrush)

A. Toxic principles: Thiaminase activity in the entire plant, even when it is dried and has become incorporated into hay

B. Animals affected: Primarily horses and cattle, sheep are rarely affected

C. Clinical signs: Acute onset; weakness, weight loss despite normal appetite, ataxia in hinquarters, prostration, paresis, paralysis, convulsions. Death within 1 to 10 days

D. Pathologic lesions. Low serum and liver thiamine levels, elevated blood pyruvate. Postmortem findings *may* include pale, flabby skeletal muscles, hydroperitoneum, major organ congestion. Polioencephalomalacia and proximal renal tubule degeneration

E. Treatment: Replace feed with good-quality alfalfa and thiamine hydrochloride. Prognosis is favorable if animal is not recumbent

XXXII. Plants containing cyanogenic glycosides include *Prunus* spp. (wild black cherry, chokecherry, plum, peach, nectarine), *Sorghum* spp. (Sudangrass, Johnsongrass), *Triglochin* spp. (arrowgrass), *Trifolium repens* (white clover), *Linum* spp. (flax, linseed plant), *Sambucus* spp. (elderberry), *Euphorbia* spp. (spurges), *Acacia greggii* (catclaw), *Phaseolus limensis* (lima bean), *Malus* spp. (apple), *Cercocarpus spp*. (mountain mahogany), number of plants in the rose family, *Hydrangea* spp. (hydrangea), *Heteromeles arbutifolia* (California holly), etc.

A. Description and Habitat: Cyanogenic (means the ability to produce cyanide) glycosides are present in more than 800 species of plants in eighty different plant families

B. Toxic principles: Cyanogenic glycosides (e.g., amygdalin, dhurrin, linamarin) are present in all parts of the plants, particularly the seeds. Freezing, plant injury, high nitrogen-low phosphorus soils, and mastication all favor the production of cyanide gas

C. Mechanism of action
 1. The intact cyanogenic glycoside and the enzyme for its hydrolysis, β-glycosidase, are present in plant cells but spatially separated. Following damage to the cells, the enzyme breaks down the cyanogenic glycoside to a sugar and an aglycone; aglycone is further converted by the enzyme hydroxynitrile lyase to hydrocyanic acid and a ketone or aldehyde. Hydrocyanic acid is rapidly absorbed through the walls of the rumen or stomach into the circulation. The cyanide reacts with ferric (Fe^{+3}) ion of cytochrome oxidase to form a stable complex that essentially stops electron transport and cellular respiration
 2. The blood is fully oxygenated but cannot be utilized by the cells. Cellular hypoxia stimulates the chemoreceptors to increase the respiratory effort and the blood becomes hyperoxygenated; animal dies from hypoxia

D. Animals affected: All animals susceptible, particularly ruminants

E. Clinical signs: Onset of clinical signs can be within a few minutes to 120 minutes and include excessive salivation, hyperpnea followed by dyspnea, weakness, muscle fasciculations, urination, defecation, tachycardia, mydriasis, lateral recumbency, convulsions, and death from respiratory paralysis

F. Pathologic lesions
 1. Blood is reportedly a bright cherry red (may not see this in many cases), and rumen or stomach contents often have "bitter almond" odor
 2. All tissues for cyanide analysis (blood, forage, rumen or stomach contents, liver, muscle) must be frozen immediately in an air tight container because the cyanide will readily volatilize
 3. Field "picrate paper" test on feed; gives qualitative cyanide analysis

G. Treatment
 1. Decontaminate if possible
 2. For large animals, sodium nitrite at 10 to 20 mg/kg as a 20% solution to induce methemoglobinemia. Cyanide preferentially binds to the ferric ion of methemoglobin to form cyanomethemoglobin. Follow with sodium thiosulfate as a 20% solution at 500 mg/kg. The sulfur in sodium thiosulfate reacts with the cyanomethemoglobin to form hydrogen thiocyanate, which is excreted in the urine
 3. Methylene blue at 4 to 6 g per 454 kg of body weight has been used alone but works very slowly and is not recommended
 4. For small animals, administer 1.65 mL of a 25% solution of sodium thiosulfate/kg of body weight and 16 mg of sodium nitrite/kg of body weight. Repeat dose in 30 minutes if no clinical response
 5. Cyanokit (hydroxocobalamin)

TOXICANTS AFFECTING THE GASTROINTESTINAL (GI) TRACT

I. Zinc, magnesium, or aluminum phosphide

A. Source: Rodenticides and grain fumigants for insect and rodent control. Stable for approximately 2 weeks under average climatic conditions; unstable in water or acidic environments

B. Toxicity
 1. Reported in all species. Secondary or relay toxicosis unusual
 2. Some products contain the emetic antimony potassium tartrate. Some contain ammonia as a detector; if phosphine gas is inhaled, will get pulmonary edema

C. Mechanism of action
 1. Extreme irritant to GI mucosa
 2. Parent compound *and* the generation of phosphine gas are accelerated in acidic environments (i.e., full stomach); a metabolic poison that noncompetitively blocks cytochrome C oxidase → blocks electron transfer and inhibition of oxidative phosphorylation → energy crisis in cells → increase in vascular permeability → CV collapse. Multiple organ involvement (heart, lungs, GI tract, kidneys, liver)

D. Clinical signs
 1. Onset within 15 minutes to 4 hours; dose dependent (death within 3 to 5 hours)
 2. Anorexia, lethargy, severe GI pain, vomiting (with or without blood), diarrhea, weakness, recumbency, deep labored respiration (severe hypotension and acidosis), respiratory distress, body tremors, salivation, running fits, seizures
 3. Death is usually the result of cardiovascular collapse and cardiac arrhythmias or conduction disturbances (myocardial injury). Pulmonary, hepatic, and renal complications. May see hypomagnesemia and metabolic acidosis

E. Lesions
 1. Gross: Nonspecific; characteristic acetylene odor (rotten fish) or garlic odor, erythema of mucosal surfaces, congestion of liver, kidney, lung; interlobular lung edema, pleural effusion, subpleural hemorrhages
 2. Microscopic: Nonspecific; fatty change, congestion of the liver and kidneys
 3. Degeneration; hyaline change; necrosis of renal tubular cells, hepatocytes, and myocardium

F. Diagnosis: Clinical signs (GI), odor of gastric contents; chemical identification. Freeze stomach contents or vomitus immediately in airtight container; phosphine gas analysis. Zinc, Mg, aluminum, phosphorus in serum, liver, kidney, stomach contents (screen only)

G. Treatment: Decontamination (gastric lavage, AC); supportive (sodium bicarbonate, Ca gluconate, corticosteroids, dextrose, B vitamins, fluid therapy)

II. Arsenic

A. Source
 1. Natural ore, thermal springs and mines
 2. Herbicides, fungicides, insecticides, rodenticides, antifoulant agents
 3. Chromate copper arsenate wood preservative (ash is the problem)
 4. Caparsolate and Immiticide (melarsamine dihydrochloride); organic arsenics

5. Soil contamination; refineries, smelters (gold tailings)

B. Toxicity
1. Dependent on exposure, species, chemical form, health status (weak, dehydrated animals, renal compromised patients more susceptible)
2. Highly water-soluble trivalent form is much more toxic than the pentavalent form. Pentavalent forms are metabolized to methylarsonic acid and dimethylarsinic acid, which are excreted through the urine
3. Two groups: Inorganic (affects GI tract) and organic (affects nervous system)

C. Mechanism of action
1. Readily absorbed from the GI tract, skin, mucous membranes, respiratory tract; excreted into urine and bile. 50% to 80% excreted within 72 hours ($T_{1/2}$=10 hours)
2. Reacts with lipoic acid to form a stable compound that disrupts SH-containing enzymes of cellular respiration
3. Potent capillary poison (affects tissues rich in oxidative enzymes; alimentary tract, kidney, liver, lung, epidermis); transudation of plasma fluids into intestinal mucosa and lumen, resulting in reduced blood volume, hypotension, shock, and circulatory collapse

D. Clinical signs
1. Acute or peracute: 2-3 days. Signs include intense abdominal pain, staggering, weakness, trembling, salivation, vomiting, diarrhea with or without mucosal shreds, fast, weak pulse, prostration, hypotension, dehydration, oliguria, normal or subnormal temperature, sudden death
2. Subacute: Several days. Signs include depression, anorexia, diarrhea with or without mucosal shreds, dehydration or PD, PU or anuria, weakness, rear limb paresis or paralysis, trembling, stupor, hypothermia, death
3. Pentavalent organic arsenic: "Happy pig syndrome"; rearlimb paresis or paralysis, blindness, maintain appetite if allowed access to food and water. Will progress to include the forelimbs

E. Lesions
1. Gross: May not see in peracute cases. With inorganic arsenic: localized or generalized hyperemia and edema of gastric or abomasal mucosa, abomasal ulcerations, and necrosis. Foul-smelling fluid, GI contents
2. Microscopic: May not see in peracute cases. With inorganic arsenic, mucosal or submucosal edema, necrosis, and sloughing of GI tract; acute renal tubular necrosis or glomerular sclerosis; hepatic fatty degeneration and necrosis. Pentavalent organic: Demyelination and axonal degeneration of peripheral nerves, espcially optic, brachial, sciatic

F. Diagnosis
1. Compatible clinical signs
a. Inorganic trivalent arsenic: GI involvement with no neurologic involvement
b. Pentavalent organic arsenic: blindness, limb paresis or paralysis
2. Compatible lesions
a. Inorganic trivalent arsenic: GI edema, erythema, ulceration, necrosis
b. Pentavalent organic arsneic: demyelination, axonal degeneration
3. Chemical analysis: Urine, blood (within 2 to 3 daysj of exposure), liver, kidney, stomach contents

G. Treatment: Decontamination, aggressive fluid and electrolyte therapy (monitor renal, electrolyte and acid-base status); chelating agents (containing sulfhydryl groups): British Anti-Lewisite (dimercaprol), thioctic acid, Dimercaptosuccinic acid (DMSA, alias succimer [Chemet]), D-penicillamine (Cuprimine), sodium thiosulfate

III. Trichothecene mycotoxins: Deoxynivalenol (Vomitoxin-DON), T-2 toxin, diacetoxyscirpenol (DAS)

A. Source: Largely produced by field fungi (but can be a storage fungi), *Fusarium* spp., on cereal grains (corn, wheat, barley). Associated with wet weather and cold temperatures when harvest is prolonged. Reported T-2 and HT-2 on grass type forages; generally in wet years

B. Toxicity
1. Primarily affects swine, cattle, poultry. Rarely in dogs because of feed refusal
2. Multiple mechanisms of action, most related to inhibition of protein synthesis

C. Clinical signs
1. Deoxynivalenol (DON, vomitoxin): Feed refusal, decreased rate of gain, diarrhea, vomition
2. T-2 toxin, diacetoxyscirpenol (DAS): Feed refusal, vomition, diarrhea, increased incidence of infection, dermatitis, oral mucosal damage. Less often: GI hemorrhage and necrosis, lymphoid necrosis, meningeal hemorrhage, shock and death

D. Lesions: No specific lesions; necrosis or hemorrhage of intestinal mucosa, bone marrow, spleen, testis, ovary

E. Diagnosis: Clinical signs (feed refusal, vomiting, failure to thrive), recent feed change; chemical analysis of feed

F. Treatment: Remove suspect feed, replace with good-quality feed; supportive

IV. Phenoxy herbicides

A. Source. Commonly used herbicides around the house, garden, and in agriculture
1. 2,4-D (2,4-dichlorophenoxy acetic acid): No. 1 used herbicide in agriculture and home use ("weed and feed")

B. Toxicity
1. All are susceptible. Dogs more susceptible because of a poor ability to excrete organic acids (tubular secretion) in urine
2. Exposure results from animals having access to treated lawns (minor risk) or to concentrated products (high risk)
3. May increase palatability of plant material and cause increases in nitrate and cyanogenic glycoside concentrations in some treated plants

C. Mechanism of action
 1. Phenoxy herbicides are plant growth regulators; they mimic the action of auxins
 2. Mechanism not well understood; direct effect on muscle membranes, causing increased irritability and rigidity followed by paralysis
 3. Rapidly absorbed from GI tract and excreted into urine unchanged
 4. Little cumulative effect is observed

D. Clinical signs
 1. Signs limited to GI and neuromuscular systems; onset within 2 to 12 hours
 2. In dogs, signs of moderate toxicosis include anorexia, vomiting, and diarrhea (may see blood). Signs of severe toxicosis include disinclination to move, myotonia, followed by weakness of the rear limbs, ataxia, depression. Less common signs include spasms, coma, opisthotonus, oral and GI ulcers
 3. In livestock (ruminants), signs include anorexia, diarrhea, depression, bloat, rumen atony, and muscle weakness

E. Pathology. Gross: Nonspecific; multiple organ congestion. Microscopic: Nonspecific; GI irritation or ulceration, renal tubule degeneration, focal hepatic necrosis

F. Diagnosis: History of exposure, clinical signs, electromyogram in dogs (increased insertional activity), chemical identification (liver, kidney, urine, serum)

G. Treatment: Decontamination (bathe, gastric lavage, AC and cathartic if no diarrhea present); maintain adequate hydration and electrolyte status, analgesics

V. Nonsteroidal antiinflammatories (NSAIDs)

A. Source: Many prescription and over-the-counter preparations. Antipyretics, analgesics, antiinflammatories

B. Toxicity: Direct or accidental consumption; most occur in dogs. Variation in susceptibility; difficult to establish a toxic dose

C. Mechanism of action
 1. Rapidly absorbed across the gastric mucosa and upper small intestine
 2. Some eliminated primarily as a conjugate of glycine or glucuronic acid (cats and neonates most sensitive)
 3. Inhibition of cyclo-oxygenase (prostaglandin synthetase) activity; lack of prostaglandin I_2 and E_2 synthesis; gastric ulceration and renal papillary necrosis
 4. Inhibition of platelet cyclo-oxygenase; increase in bleeding time because of decreased aggregation of platelets (chronic exposures)
 5. Uncoupler of oxidative phosphorylation; leads to hyperglycemia and glucosuria
 6. Stimulation of the respiratory center; respiratory alkalosis and secondary bicarbonate excretion in urine; metabolic acidosis
 7. Impaired renin secretion and enhanced tubular water and sodium reabsorption
 8. Carprofen can cause an idiosyncratic reaction in dogs; hepatocellular damage

D. Clinical signs
 1. Onset quite variable (dose-dependent): GI upset 4 to 6 hours, ulceration 12 hours to 4 days, renal problem 12 hours to 5 days
 2. Signs include depression (in 93%), anorexia, diarrhea, vomiting, abdominal pain, hyperthermia, PU or PD, tachypnea, ataxia, weakness, hematemesis, seizures

E. Clinical pathology: Often nonspecific; dependent on dose, duration, and time. May see anemia, elevated liver enzymes, azotemia, hypoproteinemia, hypernatremia, initial metabolic alkalosis followed by a metabolic acidosis. Urinalysis may show isosthenuria, casts

F. Lesions: Gastric congestion, hemorrhage, ulceration, perforation. renal tubular papillary necrosis

G. Diagnosis: Exposure, clinical signs (GI, renal), chemical analysis (serum, urine, stomach contents)

H. Treatment: Prevent ulceration or perforation and renal failure. Decontamination (emetics, AC, cathartic, gastric lavage), fluid therapy (0.45% saline in 2.5% dextrose or 0.9% saline or crystalloids, 1.5 to 3× maintenance; at least 24 to 72 hours), dopamine or dobutamine drip (enhance glomerular filtration), furosemide, sucralfate (for ulcers), H_2 antagonists, misoprostol (prostaglandin analogue to inhibit gastric acid secretion), omeprazole (proton pump inhibitor). Monitor: BUN, Cr, acid-base status, urine specific gravity, urine output, PCV; good prognostic indicators for the first several days

VI. Cantharidin (blister beetles)

A. Source
 1. Numerous genera have been given the name "blister beetles": *Epicauta* is the greatest culprit. All are in the family Meloidae
 2. Adults are phytogenous; larvae are ectoparasitic (follow grasshopper infestations and feed on alfalfa hay). Blister beetle larvae feed on grasshopper eggs, overwinter, emerge in the late spring, adults feed on alfalfa blooms. Cut but not crimped alfalfa allows beetles to leave. Crimped alfalfa kills and traps beetles

B. Toxicity: Bicyclic terpenoid. Male beetles produce cantharidin (present in hemolymph), and 92% is found in the third pair of accessory reproductive glands. Transfer of cantharidin occurs during mating. Cantharidin content can vary between 0.1% and 15% of the dry weight of the beetle. Horses and cattle commonly affected

C. Mechanism of action
 1. Lipid-soluble, highly irritating substance (acantholysis, separation of prickle cells of stratum spinosum, vesicle formation of skin and mucous membranes)
 2. Absorbed through skin and in GI tract and excreted by kidney (65% unchanged); irritation occurs. Hypocalcemia and hypomagnesemia

D. Clinical signs: GI signs predominate. Onset acute. Anorexia, fever, colic, tenesmus, diarrhea, increased frequency of urination, increased heart and respiratory rate, seizures, shock. About 10% to

20% show neurologic signs (head pressing, swaying, depression, disorientation, seizures). Shock and death within 3 to 18 hours if lethal dose

E. Clinical pathology findings include hypocalcemia, hypomagnesemia, elevated BUN, hemoconcentration, low urine specific gravity, leukocytosis

F. Lesions: May see none. Gross: Mild to moderate erythema of gastric, small intestine, or colon mucosa. Microscopic: Rare (hemorrhagic cystitis, nephritis, myocardial necrosis)

G. Diagnosis: Clinical signs (GI and renal), lesions (erythema of GI mucosa), ingestion of alfalfa hay, identification of beetle, chemical confirmation of cantheridin (urine, stomach or cecal contents, kidney, beetle)

H. Treatment: Remove suspect feed, maximize fecal and urine excretion of toxin (IV fluids, mineral oil, AC), replace fluid loss, correct Ca and Mg abnormalities, manage pain (analgesics). Treat early and aggressively

VII. *Ricinus communis* (castor bean, castor oil plant, palma christi)

A. Toxic principles

1. Toxin is ricin, a glycoprotein.Water soluble, readily absorbed from stomach and intestine. Aging and heating will inactivate ricin. Ricin can be excreted in milk
2. Highly concentrated in the seed; one seed is toxic to a dog. Seed coat is very hard and passes through th GI tract intact. If coat is broken, then there is a problem
3. Another phytotoxin present is ricinine, reportedly thought to be goitrogenic

B. Mechanism of action: Inhibitor of protein synthesis; specific inhibition of the enzyme elongation factor 2 or inactivation of 60S ribosomes

C. Animals affected: All species are susceptible. Horses and humans are most sensitive; cattle, sheep, and swine more resistant. Susceptibility of dogs and cats unknown

D. Clinical signs and clinical pathology

1. Onset within 12 to 48 hours: Nausea, abdominal pain, depression, diarrhea (often bloody) with tenesmus. Weakness, fever, sweating, muscle twitching, dullness of vision, dyspnea, convulsions, and coma have also been reported. Animals become dehydrated, hypoglycemic, and possibly hypoprothrombinemic
2. May see a leukopenia with a left shift 10 to 16 hours after ingestion. Anaphylactic reactions have also been reported
3. The most commonly reported signs in dogs are vomiting, depression, and diarrhea. Hypotension, increased cardiac output, and hemorrhage are common

E. Pathologic lesions

1. Catarrhal to hemorrhagic gastroenteritis, petechial serosal hemorrhages of the viscera, pulmonary edema, and yellow discoloration to the liver (fatty liver)
2. Myocardial, hepatic, and renal necrosis have been reported

F. Treatment: Decontaminate; use protectants and fluid therapy to prevent severe dehydration. Monitor renal and hepatic function and electrolyte, fluid balance

VIII. *Robinia pseudoacacia* (black locust, yellow locust, false acacia)

A. Toxic principles and animals affected

1. Heat-labile phytotoxins (robin, robitin, and phasing). Bark, sprouts, pods, and foliage are all toxic (not flowers). Fatalities are rare
2. Livestock are most often poisoned when they strip off the bark or from grazing sprouts or small branches that have fallen from the tree. Poisonings have been reported in horses, cattle, poultry, sheep, and humans

B. Mechanism of action: Inhibition of protein synthesis

C. Clinical signs: Onset within 1 hour; anorexia, depression, stupor, weakness (posterior paralysis and laminitis reported in cattle and horses), nausea, vomiting, pupillary dilatation, dyspnea, tachycardia, weak irregular pulse, and diarrhea

D. Pathologic lesions: Inflammation and edema of GI mucosa; may see hepatic and renal degeneration and necrosis in poultry

E. Treatment: Symptomatic and supportive

IX. *Ranunculus* spp. (buttercups)

A. Toxic principles and mechanism of action

1. Ranunculin is converted to protoanemonin (a GI irritant) by hydrolysis when plant is crushed. Protoanemonin is a volatile and bitter tasting oil and undergoes spontaneous polymerization to innocuous anemonin, so toxicity is lost upon drying
2. Highest concentrations are in the leaves at the beginning of the flowering stage. Large amounts of the plant must be consumed (spring and early summer)

B. Animals affected: Most commonly observed in cattle, although all grazing animals are susceptible. All buttercups are considered unpalatable

C. Clinical signs: Excessive salivation, reddened oral mucosa, abdominal pain, diarrhea with black fetid feces; depression or excitation, muscle tremors, temporary blindness, prostration, convulsions, death. Hematuria and reddish discoloration to the milk in cattle

D. Pathologic lesions: Nonspecific: Erythema and hemorrhage of the mucosal surfaces, congestion of the lungs, liver and kidney, and excessive fluid accumulation in the thoracic and abdominal cavities

E. Treatment: Symptomatic and supportive. Mineral oil may help protect the GI tract

X. *Euphorbia* spp. (spurge, euphorbia)

A. Toxic principles: The polycyclic diterpenoids euphorbon and euphorbin, present in the milky acrid juice. All parts of the plant are toxic but rarely are eaten since they are highly unpalatable. Toxicity is not lost in drying

B. Animals affected: All species susceptible: Horses, cattle, sheep, cats, dogs, humans

C. Clinical signs
 1. Contact with the juice may cause severe blistering of the skin and intense pain if exposed to open cuts or eyes
 2. Oral ingestion: Severe irritation of the mouth and GI tract (excessive salivation, abdominal pain, vomiting, diarrhea, and weakness). Fatalities are uncommon
 3. *Euphorbia maculata* causes photosensitization in lambs

D. Pathologic lesions: Erythema, edema, and inflammation of the GI mucosa

E. Treatment: Symptomatic and supportive; decontamination if appropriate, dilution with milk or egg white, fluids, electrolytes

F. Prevention and control: Light infestations of pastures should not be a problem because most spurges can be grazed to a limited degree. Mowing and reseeding are helpful for heavier infestations as well as light restocking. Provide supplemental forage when desirable forage is scarce

XI. Poinsettia: Highly overrated as a poisonous plant but can cause clinical signs in some animals as described above

XII. Bulbs of *Tulipa* spp. (tulip), *Narcissus* spp. (daffodil, jonquil), *Brunsvigia rosea* (naked lady), *Iris* spp. (iris), *Amaryllis* spp. (amaryllis), *Hyacinthus* spp. (hyacinth)
 A. Description, habitat: Common garden ornamentals
 B. Toxic principles and mechanism of action: Bulbs contain high concentrations of various alkaloids (e.g., narcissine, narcipoietin, lycorine in daffodils)
 C. Clinical signs: Vomiting, severe gastroenteritis; tremors, convulsions. Hypotension and death may occur but are unusual
 D. Treatment: Symptomatic and supportive

XIII. *Solanum* spp., *Lycopersicon* spp. (nightshades, tomato, potato, Jerusalem cherry, horse nettle, bull nettle)
 A. Toxic principles
 1. Most contain the steroidal glycoalkaloid solanine. Solanine is broken down into solanidine (primarily responsible for effects on the nervous system). Other alkaloids and saponins are most likely responsible for GI signs. Some have cardiac effects (profound bradycardia); others contain atropine-like compounds
 2. Situations of overgrazing: The leaves and green fruits are generally considered toxic, except *S. eleagnifolium* (silverleaf nightshade), in which ripe fruit is more toxic. Solanine content increases with the maturity; toxicity is not lost upon drying
 B. Animals affected: All species are susceptible
 C. Clinical signs
 1. GI and nervous signs: Excessive salivation, anorexia, vomiting, diarrhea, abdominal pain, drowsiness, salivation, frequent urination and diarrhea, colic, depression, muscle weakness, mydriasis, trembling, dyspnea, nasal discharge, rapid weak pulse, bradycardia, rear limb paralysis, coma, and death. If acute, renal failure, anemia, and intravascular hemolysis
 2. Course varies from sudden death to 3 to 4 days, depending on amount ingested. Pigs, cattle, horses: reports of "potato dermatitis." Neurologic disease associated with ataxia, hypermetria, hyperesthesia, head and thoracic limb extension, opisthotonus, nystagmus and falling
 D. Pathologic lesions: Nonspecific. Hyperemia, edema, and ulceration of the GI mucosa, hepatic congestion. Progressive vesicular storage disease in cerebellar Purkinje cells; vesicular storage in axons of cerebellar granular layer and/or cerebellar white matter
 E. Treatment: No specific treatment; symptomatic and supportive

XIV. *Arisaema triphyllum* (Jack-in-the-pulpit), *Dieffenbachia* spp. (dieffenbachia, dumbcane), *Philodendron* spp. (philodendron), *Colocasia* spp. (elephant's ear), *Monstera* spp. (split-leaf philodendron), *Lysichitum americanum* (skunk cabbage), *Calla* spp. (wild calla)
 A. Toxic principles: All contain insoluble oxalates and oxalic acid; some may also contain proteolytic enzymes, which trigger the release of kinins and histamines. Calcium oxalate crystals mechanically irritate GI mucosa
 B. Clinical Signs: Immediate onset of pain and irritation: head shaking, excessive salivation, swelling of the mucous membranes of the pharynx and tongue, dyspnea. Vomiting, diarrhea, and secondary fluid and electrolyte imbalances are possible. Rarely irregular heart beat, mydriasis, coma, renal disease, and death
 C. Treatment: Symptomatic and supportive (rinse mouth, antihistamines, fluids); signs usually abate within 2 to 4 hours but may persist for days in unusual cases

XV. Christmas plants: Mistletoe (*Phoradendron* spp. and *Viscum* spp.), holly (*Ilex* spp.), and *Poinsettia* spp.
 A. *Phoradendron serotinum* is the traditional American mistletoe
 1. Phoradendrons are parasitic plants that grow on trunks and branches of trees. Thick, leathery, smooth-edged, opposite leaves. Berries are globose and can be white or pinkish depending on species
 2. Leaves and stems are toxic; the berries can be toxic if enough ingested. The toxin is phoratoxin, a toxic lectin. Serious poisonings are rare
 3. Abdominal cramping, emesis, diarrhea within a few hours of ingestion; increase or decrease in blood pressure, seizures, decreased heart rate, peripheral vasoconstriction (oxytocic effect), cardiovascular collapse rare
 4. Treatment: Supportive (fluid and electrolyte replacement)
 B. *Viscum album* is the European mistletoe
 1. Stems are branched and leaves 2 to -3 in. long, thick, leathery, and usually a pale yellowish

green. Fruit is a sticky white berry. Leaves and stems are toxic; berries are harmless. Viscumin is the toxin
2. Signs of severe gastroenteritis (vomiting, abdominal pain, diarrhea) within a few hours after ingestion. Treatment is symptomatic and supportive

C. *Ilex aquifolium* (holly, English holly, European holly, Oregon holly), *Ilex opaca* (American holly), and *Ilex vomitoria* (yaupon, Appalchian holly, Carolina tea, deer berry, emetic holly)
1. Evergreen trees with stiff leathery leaves, with red or yellow berries. Berries are toxic; leaves are thought to contain caffeine-like compounds
2. Poisonings are generally mild and include vomiting, abdominal pain, and diarrhea. Treatment is symptomatic and supportive

TOXICANTS AFFECTING THE CIRCULATORY SYSTEM

I. Acetaminophen
A. Source
1. Variety of aspirin-free pain relievers; strictly an analgesic and antipyretic, not an antiinflammatory
2. Common in cats and dogs: accidental, intentional, or malicious

B. Toxicity: Common in cats and dog; male cats more susceptible than female (especially Hepatic failure)

C. Mechanism of action
1. Absorption is rapid from GI tract; within a few hours
2. Acetaminophen is metabolized in dogs by P-450 (isoenzymes 2E1 and 2A2) via conjugation with glucuronides (75%) and sulfates (20%), then excreted in the bile and urine about 5% unchanged. For cats it is sulfation (90%), cysteine conjugation (5%), and glucuronidation (1%). A small amount is oxidized to reactive intermediate (*n*-acetyl-*p*-benzoquinoneimine). These reactive intermediates are scavenged by glutathione and excreted as inactive mercapturic acid derivatives
a. Dog and cat: At elevated doses, sulfation and glucuronidation pathways are overloaded; leads to prolonged high concentrations of APAP and increases amount of APAP, which is bioactivated to the toxic intermediate. Cat has capacity-limited acetaminophen elimination (sulfation) at doses approximately one tenth of those observed in dogs. Levels of glutathione become exhausted allowing these reactive metabolites to react with cellular macromolecules → cellular necrosis or lysis (target: erythrocytes and liver)
b. Cat is deficient in UDP-glucuronyl transferase and has more readily available acetaminophen, which is oxidized to reactive intermediates.

D. Clinical signs and clinical pathology
1. Cats: Develop within 6 to 24 hours; major initial effect is on the RBCs (lysis, methemoglobin formation, and hypoxia). The higher the exposure dose, the greater the chance of affecting the liver. Signs include anorexia, hypersalivation, vomition, depression, weakness, facial and paw edema (by 12 to 24 hours), tachypnea, cyanosis, methemoglobinemia, Heinz body anemia, hemolysis, hemoglobinemia, hemoglobinuria. Death from tissue hypoxia from methemoglobinemia. Blood is brown, mucous membranes are white or cyanotic
2. Dogs: Signs generally associated with acute centrilobular necrosis (renal necrosis also). Depression, anorexia, vomition, abdominal pain (may recover after this phase and never know exposure occurred), mild hemolysis, hemoglobinuria, hepatic necrosis, icterus, weight loss, increased liver enzymes, methemoglobinemia, facial and paw edema

E. Diagnosis
1. History of potential exposure: Usually accidental access, intentionally administered by guardians, malicious poisoning
2. Clinical signs, clinical pathology changes: Methemoglobin, hemolysis and hepatic dysfunction. Blood will be chocolate brown, mucous membranes pale or cyanotic
3. Gross and histologic lesions: Evidence of hemolysis (hemosiderin, tubular casts); hepatic diffuse centrilobular necrosis, hydropic degeneration, biliary stasis
4. Chemical analysis: Serum

F. Treatment depends of presentation and whether asymptomatic or symptomatic. Often too late due to rapid GI absorption.
1. Decontamination (emetics, gastric lavage, AC, cathartics)
2. Sulfhydryl groups or sulfate donors: *N*-acetylcysteine (Mucomyst) to bind toxin and decrease methemoglobin formation, sodium sulfate
3. Ascorbic acid, methylene blue: To convert methemoglobin back
4. Supportive (parenteral fluids, electrolytes, blood transfusions, oxygen)
5. Monitor liver enzymes
6. Cimetidine (P450 inhibitor); lactulose, neomycin or metronidazole (liver failure); plasma, glucose, vitamin K_1, blood products (coagulopathy, anemia)

II. Nitrate or nitrite
A. Source
1. Consumption of nitrate-accumulating plants (Sudan grass, Johnson grass, sorghum, fireweed, beets, rape, corn, oats, wheat, fescue, alfalfa, pigweed, lamb's quarter, dock), water (rarely the source), animal wastes, fertilizers
2. Nitrogen-nitrate uptake by plant is difficult to predict; species of plant, soil acidity, moisture, sunlight, stress, herbicide treatment, frost, drought

B. Toxicity
 1. Most in ruminants: Ingestion of nitrate-contaminated feed. Can tolerate higher levels of nitrate in feed if they are acclimated with access to good-quality carbohydrates. Susceptibility depends on rate of intake, degree of adaptation, diet, metabolic state as influenced by age, pregnancy or disease
 2. Monogastrics resistant to effects of nitrate: Might see colic in greater than 1.5%

C. Mechanism of action. Nitrate (NO_3) is reduced by rumen microorganisms to nitrite (NO_2); nitrite oxidizes hemoglobin (ferrous Fe^{2+}) to methemoglobin (ferric- Fe^{3+}); incapable of O_2 transport, leads to oxygen deficit. Methemoglobin reductase in erythrocytes becomes overwhelmed

D. Clinical signs
 1. Onset 0.5 to 4 hours, death in 6 to 24 hours. Either die or recover; excreted in urine
 2. Signs include dyspnea, ataxia, diarrhea, excessive salivation, muscle tremors, tachycardia, rapid, weak pulse, convulsions (or can be a 'quiet' death). Death occurs when methemoglobin levels are greater than 70%. Blood will have a chocolate brown appearance. Mucous membranes cyanotic
 3. If pregnant animals survive acute insult, may abort 48 to 72 hours later or longer
 4. Field observations implicate sublethal nitrate toxicosis with abortion and decreased milk production

E. Clinical pathology and lesions. Nonspecific. Brownish or pale, cyanotic cast to tissues and mucous membranes (will not see if an animal has been dead for longer period; often times difficult to see), congestion of visceral organs, oral and GI ulceration

F. Diagnosis: History of ingestion, clinical signs (multiple animals, quick recovery, abortions), chemical analysis: Methemoglobin (stable for 4 hours if not preserved); nitrate analysis of feed, water, ocular fluid (enucleate), serum, plasma (frozen/chilled). Representative sampling a must

G. Treatment: Methylene blue; avoid stress

III. Zinc

A. Source: Galvanized containers, cages, water or soil contamination from mining and smelting operations, zinc nuts, bolts, nails, zippers, toys, zinc oxide ointment (not common, cause GI irritation only), U.S. pennies minted since 1983, Canadian pennies minted from 1997-2001. Zinc sulfate foot baths for large animals

B. Toxicity
 1. Relatively nontoxic because does not *tend* to accumulate in body tissues; excreted via bile, urine, and pancreas
 2. In cases of acute toxicosis, acute hemolytic crisis, seen most commonly in small dogs, cats, pet birds, captive zoo animals
 3. Onset varies: Form of zinc, species, dietary constituents (soil, minerals, protein)

C. Clinical signs and clinical pathology
 1. Signs include vomiting, diarrhea (initially will mimic GI upset), anorexia, icterus, hemolysis (may see Heinz bodies)
 2. Clinical pathology findings include hemoglobinemia, hemoglobinuria (may have effect on hematopoiesis), neutrophilia, monocytosis, elevated ALP and other liver enzymes, glucose abnormalities, elevation in amylase and lipase, regenerative macrocytic anemia (rapid decline of PCV), renal tubular necrosis (azotemia, hyperkalemia, oliguria, isosthenuria), DIC

D. Lesions
 1. Kidney: Tubular necrosis with hemoglobin casts
 2. Liver: Periacinar to midzonal hepatic necrosis with pigment accumulation, hemosiderosis. Lesions may not be as severe as with copper
 3. Pancreas: Varying degrees of inflammation, necrosis, and fibrosis
 4. GI: Mucosal inflammation, necrosis

E. Diagnosis: History of exposure, clinical signs, serum, liver, kidney, pancreas Zn levels

F. Treatment: Remove source, supportive (fluids, transfusions, electrolytes), chelators (CaEDTA, D-penicillamine) are of questionable value. Complications: renal, hepatic, pancreatic dysfunction

IV. Anticoagulant rodenticides

A. Source
 1. Rodent baits, improperly cured or moldy sweet clover (*Melilotus* spp.), sweet vernal grass or vanilla grass (*Anthoxanthum odoratum*)
 2. Most formulations contain small concentrations (less than 1%) of active ingredient, grain-based baits in pellets, meals, wax blocks, powders, sprays; common to see tan, blue, green, turquoise
 3. Warfarin, pindone, valone, coumafuryl, brodifacoum, bromadiolone, chlorophacinone, diphacinone (diphenadione), phenindione, difenacoum, and difethialone

B. Toxicity
 1. Potentially hazardous to all mammals and birds. Dogs, cats most frequently affected. Secondary toxicosis uncommon, but can occur (good mousers: Owls, dogs, cats)
 2. Some may secrete into milk; exposures can occur in utero

C. Mechanism of action
 1. Interferes with the role of vitamin K in the synthesis of clotting factors II, VII, IX, and X in the liver. Vitamin K acts as a cofactor in post-ribosomal modification of factors; it is oxidized to its epoxide form. Vitamin K epoxide is inactive and requires reduction back to its active form. Anticoagulant rodenticides act by inhibiting vitamin K epoxide reductase → concentration of vitamin K at the active site is reduced → impaired synthesis of clotting factors.
 2. $T_{1/2}$ of factors II, VII, I,X and X are 41, 6.2, 13.9 and 16.5 hours, respectively; why there is a delay of 2 to 5 days in clinical signs (clotting abnormalities will occur earlier – 24 to 48 hours)

following ingestion. See prolongation of intrinsic, extrinsic, and common coagulation pathways
3. $T_{1/2}$ of the anticoagulant rodenticides vary: 14 hours to 6 days. This has important implications when considering duration of treatment

D. Clinical signs
1. Onset: 2-4 days (dependent on compound)
2. Clinical signs, cardiopulmonary changes, lesions, and treatment options reflect site, speed, and amount of hemorrhage: Can occur anywhere. Signs include sudden death, anemia, weakness, lethargy, dyspnea, coughing, hematemesis, epistaxis, melena, hematomas, pallor, paresis, ataxia, seizures
3. Clinical observation: 50% bleed into lungs (epistaxis, depression, weakness, coughing, pallor); other 50% will bleed anywhere: Thymus, retroperitoneal, urinary bladder, CNS, spinal cord, post surgical site

E. Clinical pathology
1. Changes are speed, site, and volume of hemorrhage dependent
2. Findings include anemia, with or without regeneration, thrombocytopenia (rare to go below 35,000), leucocytosis (neutrophilia, left shift), hypoproteinemia, increase alkaline phosphatase, elevated fibrinogen and fibrin degradation products (FDPs) (50%), and low PaO_2

F. Lesions
1. Gross: Hemorrhage into lungs and thoracic cavity (50%), abdominal cavity, mediastinum, GI tract, brain, spinal cord. Can occur almost anywhere
2. Microscopic: Hemorrhage, centrilobular hepatic necrosis

G. Diagnosis: Identification of specific product key to successful management
1. History of baiting; most are free roaming dogs. Always assume long acting
2. Appropriate clinical signs: Hemorrhage of unknown cause
3. Lesions compatible with a bleeding disorder can occur anywhere. Clinical pathological changes are time dependent and site dependent. Perform CBC, serum chemistry panel, hemostasis screen, crossmatch. Do not rule out if not anemic
4. Radiographs: Thoracic or abdominal; find site of hemorrhage; can be helpful in treatment (abdominocentesis, pericardiocentesis, thoracocentesis)
5. Prolongation of clotting factors: ACT (in-house or intrinsic + common); OSPT-PT or extrinsic + common; APTT - intrinsic and common. OSPT most sensitive due to short half-life
6. PIVKA (Proteins induced by vitamin K antagonists) or Thrombotest (1.0 ml citrated plasma). Limitations: Tests for the precursors are not specific; abnormal before clotting times abnormal
7. Chemical analysis: Blood (antemortem, EDTA), liver (postmortem), GI contents if acute

H. Treatment options: Bleeding vs. the nonbleeding patient
1. Nonbleeding patient
 a. Decontamination (emetics, AC, cathartics)
 b. Vitamin K_1: Loading dose of 2.5 to 5.0 mg/kg subcutaneous, orally, followed by 1.25-2.50 mg/kg orall twice daily for 7 days (warfarin) up to 21 to 30 days (all others). Better absorption if followed by a fatty meal
2. Bleeding patient
 a. Maintain cardiovascular support (fluids, fresh-frozen plasma or blood). Plasma gives a faster response than vitamin K_1. Patient with abnormal clotting times needs plasma
 b. Vitamin K1: Loading dose of 2.5 to 5.0 mg/kg subcutaneous, oral, followed by 1.25 to 2.50 mg/kg orally twice daily for 7 days (warfarin) up to 21 to 30 days (all others). Better absorption if followed by a fatty meal
 c. Exercise restriction (stall rest and fresh alfalfa for horses), attention to client compliance. Fresh, dark green plants, liver, and fish meal high in vitamin K. Oxygen support; antibiotics to prevent secondary infections
 d. Monitor clotting times 2 to 3 days after cessation of vitamin K_1 therapy

V. *Allium* spp. onions, garlic, chives

A. Toxic principles
1. S-alk(en)ylcysteine sulfoxide (e.g., S-methyl-L-cysteine sulfoxide), along with breakdown products dipropyl disulfide, 1-propenyl and 2-propenyl disulfides, are hemolytic agents; highest concentrations are present in the bulb
2. Varying toxicity with form of onion ingested, raw, crushed, cooked, dried

B. Mechanism of action
1. Potent oxidizing effect on RBCs
2. Disulfide agents deplete RBC concentrations of reduced glutathione or decrease activity of the enzyme glucose 6-phosphate dehydrogenase resulting in reduced glutathione production → denaturation and precipitation of hemoglobin in Heinz bodies (formation of mixed disulphide linkages between the globin chains of hemoglobin and glutathione, which precipitate within the cell). The RBC membrane weakens and eventually ruptures, or RBCs removed by the spleen. Disulfide agents also bind to cytochrome oxidase (affects cellular respiration) and also may see the formation of sulfhemoglobin. Methemoglobinemia may also occur

C. Animals affected: Cattle are most susceptible (some suggestion that young cattle appear to be more resistant than adults); horses, dogs, and cats are of intermediate susceptibility; sheep and goats are most resistant

D. Clinical signs and clinical pathology
1. Inappetance, pale or icteric mucous membranes, weakness, rapid breathing, rapid heart

rate, diarrhea, staggering, collapse, decreased rumen motility; Heinz body formation, hemolysis, anemia, hemoglobinemia, hemoglobinuria, elevated conjugated bilirubin, elevated lactate dehydrogenase. Abortions may occur due to fetal hypoxia. Appears within 24 hours up to several days after ingestion
2. Onion odor to the breath, urine, milk, feces, and tissues. Hemoglobinuric (hypoxic?) nephrosis can be a long-term sequela

E. Pathologic lesions: Enlarged spleen, icterus, hepatomegaly, renomegaly. Hemosiderosis of proximal renal tubules, Kupffer cells, and macrophages of spleen. May see ischemic nephrosis, hepatic periacinar necrosis
F. Treatment: Remove source, blood transfusion, IV fluids, vitamin E supplement. Reversible if not moribund

VI. *Acer* spp. (maple, red maple in particular)
A. Toxic principles: Unknown (some type of oxidant; gallic acid has been implicated). Wilted or dried leaves are especially toxic. Reported most commonly in late summer and fall. Should consider all *Acer* spp. potentially toxic
B. Mechanism of action: Unidentified toxin (some type of oxidant damage) causes an acute hemolytic anemia, methemoglobinemia, and Heinz body formation
C. Animals affected: Almost all reports have been in horses; report in two alpacas
D. Clinical signs and clinical pathology: Depression, anorexia, cyanosis, icterus, tachycardia, polypnea, brown discoloration to blood. Anemia, methemoglobinemia, hemoglobinuria, Heinz bodies. Appear in less than 48 hours
E. Pathologic lesions: Generalized icterus, splenomegaly, hepatomegaly; centrilobular hepatic degeneration, hemoglobinuric nephrosis, erythrophagocytosis by splenic, adrenal, and hepatic macrophages
F. Treatment: Same as onion (see above)

VII. Cruciferae (mustard family) *Brassica* spp. (mustard, rutabaga, turnip, rape, canola, kale, cabbage, broccoli, brussel sprouts), *Erysimum* spp. (wormseed mustard), *Raphanus* spp. (radish), *Thlaspi* spp. (stinkweed, fanweed, pennycress), *Barbarea* spp. (wintercress), *Amoracia* spp. (horseradish)
A. Toxic principles and mechanism of action: Vary with plant and plant part. Most will be harmful to animals only under certain specific conditions
1. Indole glucosinolates (derived from tryptophan) converted to isothiocyanates (volatile oils) upon mechanical breakdown of plant or seeds. Isothiocyanates are GI irritants. Can be transferred in milk
2. Other breakdown products of glucosinates are 5-vinyloxazolidine-2-thione (goitrin, comes from progoitrin via myrosinase) and thiocyanate ion. The former interferes with thyroid hormone synthesis and thiocyanate ion competes with iodine for uptake by the thyroid gland
3. S-methyl cysteine sulfoxide undergoes breakdown to dimethyl disulfide, causes hemolysis and Heinz body anemia
4. Many accumulate nitrate under conditions of heavy nitrogen fertilization or stress
5. Pneumotoxic metabolite (maybe similar to 3-methyl indole) responsible for acute pulmonary emphysema and edema
6. High thiaminase-like activity or high S content associated with polioencephalomalacia and copper deficiencies
7. Other syndromes: Rapeseed associated with reversible blindness and hepatic necrosis accompanied by photosensitization; bile duct hyperplasia and megalocytosis of renal tubular epithelium. Bloat, reproductive inefficiencies, and enterotoxemia in various species
8. Equine dysmaturity syndrome: Mares ingest mustard during gestation

B. Disease of cattle that graze turnips: Bloat, pulmonary emphysema, anemia, polioencephalomalacia, reproductive inefficiency, hypothyroidism, nitrate poisoning, copper and iodine deficiencies, enterotoxemia
C. Animals affected: All livestock susceptible
D. Clinical signs and pathologic lesions: Depend on species affected, amount and type of plant ingested
1. Abdominal pain, vomiting, diarrhea
2. Enlarged thyroid glands or normal-size thyroid glands that are hyperplastic; increased anestrus; affected young often born weak and die shortly after birth
3. One to three weeks after ingestion, see jaundice, hemoglobinuria (may not see acute hemolysis with significant hemoglobinuria; more often see a low-grade anemia, which has a deleterious effect on health and productivity), anorexia, fever. Macrocytic hypochromic in cattle, microcytic normochromic in sheep, Heinz body formation. Swollen pale liver, jaundice, dark brown kidneys, splenomegaly. Hepatic and renal hemosiderosis, renal tubular degeneration
4. See nitrate accumulators
5. Acute onset of tachypnea, expiratory dyspnea. Lungs are bilaterally rubbery, wet, and heavy; blood-tinged fluid fills alveolar and interstitial spaces. Prominent emphysematous distension of interlobular septa
6. Twitching of ears and eyelids, champing of jaws, blindness, wandering aimlessly, progress to recumbency, nystagmus, convulsions. Cerebral edema, thinning and yellow-gray discoloration of the occipital and parietal cortices. Laminar cortical necrosis, accumulations of microglia filled with cytoplasmic lipid vacuoles
7. High S content interferes with copper absorption
8. Dysmaturity syndrome in foals: Incomplete ossification, mandibular prognathism, tendon rupture
9. Cholesterol levels often drop in animals grazing *Brassica* spp.

E. Treatment: Supportive, supply iodine to diet, methylene blue, thiamine hydrochloride, mannitol, dexamethasone, copper and selenium supplement. Prognosis is poor

VIII. *Melilotus alba, officinalis* and *indica* (white sweet clover, common yellow sweet clover, small flowered yellow sweet clover) and *Lespedeza sericea*
A. Toxic principles
1. Coumarin is present as a glycoside (melilotoside). Dimerization and oxidation of coumarin yield dicoumarol (also called bishydroxycoumarin). This process takes place when the clover is cut and baled during high-moisture conditions
2. Improper curing conditions allows for the growth of certain fungi within the stems (*Aspergillus*, *Penicillium*, *Mucor,* and *Hemicolor*). This process occurs in both hays and silage
3. Common during the winter after ingesting damaged feed for 2 weeks or longer (dependent on concentration of dicoumarol present). Not all moldy sweet clover contains dicoumarol
B. Mechanism of action: Dicoumarol interferes with vitamin K epoxide reductase, which is necessary for regeneration of active vitamin K. Vitamin K is necessary for the posttranslational activation of the clotting factors II, VII, IX, and X. These factors are ultimately depleted within the circulation and hemorrhage occurs
C. Animals affected: Cattle; younger animals more susceptible (rare in other species)
D. Clinical signs
1. Weakness, pallor, tachycardia, cutaneous hematomas, prolonged bleeding from minor wounds; blindness from hemorrhage into the eye; lameness from hemorrhage into the joint or muscle; dyspnea from hemorrhage into the thoracic cavity, lungs, or mediastinum; frank blood in the oral cavity, nostrils, or at urogenital orifices; hemorrhage into the CNS may result in paresis, paralysis, or convulsions. Abortions may occur
2. Death may occur within a few hours or be delayed for up to a week or longer. Calves can be affected in utero
E. Clinical pathology: Regenerative anemia, increased bleeding time and prothrombin time (PT), activated partial thromboplastin time (APTT), and activated coagulation time (ACT)
F. Pathologic lesions: Generalized hemorrhage, centrilobular necrosis from hypoxia
G. Treatment: Replace suspect feed with quality alfalfa hay, avoid stress, correct hypovolemia and clotting factor deficits (vitamin K_1, fluid therapy, blood transfusion)

IX. *Pteridium aquilinum* (bracken fern, brake-fern)
A. Toxic principles, mechanism of action, animals affected
1. Most poisonings occur in late summer or winter. The young plants and rhizomes are most toxic, either green or dried
2. Clinical disease usually occurs after ingesting significant amounts of plant material over a long period of time (e.g., 20% of diet for 30 days or more). Unpalatable; most poisonings occur as a result of the immature plant becoming incorporated into hay
3. Toxins are excreted in the milk and may affect offspring
B. Animals affected
1. Monogastrics, primarily horses. Thiaminase activity: Thiamine destroyed in GI tract before absorbed. Thiamine is important as a cocarboxylase in the metabolism of fat, carbohydrates, and protein. Thiamine deficiency results in impaired pyruvate utilization (pyruvate levels in circulation rise), leading to inadequate ATP production by the tricarboxylic acid (TCA) cycle. The disease is called "bracken staggers."
2. Ruminants, primarily cattle: Bone marrow depression. Toxic principle, ptaquiloside or quercetin, ultimately causing thrombocytopenia, anemia, and leukopenia
3. Cattle: Ptaquiloside or quercetin causing "bovine enzootic hematuria"
4. Cattle or sheep: Ptaquiloside or quercetin causing upper GI and bladder carcinomas
C. Clinical signs
1. Neurologic in appearance. Onset of signs is acute: Loss of weight despite good appetite, lethargy, incoordination (swaying from side to side), bradycardia**,** wide stance, arched back. Progresses to severe tremors, recumbency, opisthotonous, convulsions
2. Signs associated with thrombocytopenia, leukopenia, and anemia terminally. Clinical signs are highly variable: Rough coat, listlessness, anorexia, hemorrhage (petechiation and ecchymoses, cutaneous hematomas, melena, epistaxis), hyperthermia, secondary bacterial infections are common. Signs may appear even after contaminated feed has been removed (1 to 2 weeks). Death within 2 to 10 days
D. Clinical pathology
1. Elevated blood pyruvic acid levels (6 to 8 μg/dL; normal range, 2 to 3 μg/dL) and reduced blood thiamine levels (2.5 to 3.0 ug/dL; normal range, 8-10 μg/dL)
2. Thrombocytopenia, anemia, leukopenia, prolonged bleeding time
E. Pathologic lesions
1. Often nonspecific; polioencephalomalacia in horses
2. Multiple hemorrhages and bacteremia, edematous GI mucosa, pale bone marrow, focal necrosis and ulceration of the GI tract
F. Treatment: Thiamine hydrochloride, broad spectrum antibiotics, blood transfusions

TOXICANTS AFFECTING THE SKIN

I. Chronic selenium poisoning (bobtailed disease)
A. Source
1. Selenium containing forages, selenium feed additives, injectable selenium supplements, paints, shampoos, varnishes

2. Obligate indicator plants: Require selenium for growth so tend to be found in seleniferous soils. Often have strong odor and are unpalatable
3. Facultative indicator plants, passively absorb selenium

B. Toxicity
1. All species susceptible; horses appear to be most sensitive
2. Result of grazing selenium-containing plants or excessive selenium added to feeds

C. Clinical signs
1. Chronic: Lameness, rough hair coat, hair loss (tail, mane or body), horn and hoof deformities (circular break in hoof below coronary band), emaciation
2. Signs can vary between species and dependent on duration of exposure; multiple organ effect, acute or chronic. If selenium levels are high enough, animals will stop eating; liver, kidney, and heart may be affected; may see reproductive problems (decreased conception rates)
3. In acute toxicoses, selenium is excreted from lungs in form of dimethyl selenide, causing massive capillary damage → hemorrhage, edema → dyspnea, depression. Can see "acute" death. Also in swine; feed refusal and paralysis (neurologic)

D. Lesions
1. Hoof lesions: Separation of the hoof keratin from underlying tissue beginning at the coronary band
2. May see (in addition to skin, hair, and hoof lesions) cirrhosis and atrophy of the liver, atrophy of the heart, degeneration and necrosis of the liver and kidney, hemorrhagic gastritis, malacia of the ventral horns of cervical and lumbar spinal cord, and skeletal and myocardial degeneration and necrosis (particularly in acute, peracute, subacute cases)

E. Diagnosis: History of exposure, clinical signs, analysis of blood or serum (antemortem), liver or kidney (postmortem), forage, water, hair, hoof

F. Treatment: No effective treatment; remove animals from area. May take weeks to months for tissue levels to decline to normal

II. Fescue

A. Three distinct clinical syndromes
1. Summers syndrome (Slump) in cattle
2. Reproductive problem in mares, cattle, sheep
3. Fescue foot: dry gangrene of extremities

B. Source: Tall fescue (*Festuca arundinacea*) containing endophyte *Acremonium (Neotyphodium) coenophialum*. About 35 million acres: 95% are infected. If grass contains more than 5% infected, can be a problem. Cattle primarily affected during winter (fescue foot)

C. Toxicity and mechanism of action
1. Toxins: Loline alkaloids (#7) and ergot-like alkaloids (#6). Ergovaline constitutes 84% to 97% of the total alkaloid content. Other lysergic acid compounds may also play a role
2. Two mechanisms: Peripheral vasoconstriction via α adrenergic receptors; suppress prolactin secretion via interaction with D_2-dopamine receptors

D. Clinical signs and lesions
1. Onset quite variable
2. Summer slump: Rough hair coat, rapid breathing, hyperthermia, decreased feed intake and ADG; occurs in the summer
3. Reproduction problems: Prolonged gestation, thickened placentas, large weak young, dystocia, agalactia, abortions (can see in all three diseases)
4. Fescue foot: Reluctance to move, lameness, red swollen fetlocks, cracks in coronary band (hindlimb primarily affected), dry gangrene (ischemic necrosis), loss of appetite: tip of tail, ears, digits: Need to palpate

E. Diagnosis: History of ingesting tall fescue, seasonal incidence, clinical signs. Measure prolactin levels; test alkaloid content of forage and urine

F. Treatment: Limit intake, reduce stress; give metaclopramide, domperidone, and sulpiride (dopamine D_2 antagonists); give perphenazine (prevents agalactia in horses)

III. Ergot

A. Source
1. Sclerotia of the fungus: *Claviceps purpurea*, *paspalli* and *fusiformis*. Cool, wet weather during flowering; fungi infects the stigma and ovary of cereal grains and grasses. Ergot spores enter the flower and germinate, and a mycelial *sclerotia* replaces the seed
2. Commonly affects rye, barley, wheat, triticale; any seed is susceptible
3. The sclerotia are hard, black, elongated bodies that are slightly larger than the seed grain they are replacing

B. Toxicity and mechanism of action
1. Sclerotia can contain 12 ergopeptide alkaloids (derivatives of lysergic acid). Ergotamine usually present in highest concentration. *Ergonovine* also high
2. Actions: Peripheral vasoconstriction via alpha adrenergic receptor stimulation. Also oxytocic
3. Most poisonings reported in cattle and poultry. Famous historically in people
4. Major signs: Dry gangrene and convulsion (brain ischemia) or GI disorder

C. Clinical signs
1. Onset: 2 to 6 weeks; highly variable depending on dose. Initially see reddening and swelling of the extremities. Progress to dry gangrene ('freezing feet off') of ear tips, tail, digits; sloughing off of hooves. Need to palpate
2. Feed refusal commonly initially observed
3. Abortions in cattle and sheep
4. Moderate exposures: Dairy cows: ↓ Feed intake and milk production
5. Other reported problems: Loss in reproduction efficiency, internal hemorrhages, decreased tolerance to heat, ataxia, convulsions, paralysis, colic, regurgitation, diarrhea, constipation
6. Weak, small piglets; agalactia in the sows

D. Diagnosis: Find sclerotia bodies (impossible if pelleted), analyze feed for ergotamine
E. Treatment and prevention: Remove feed; plow under (tough to get rid of)

IV. *Hypericum perforatum* (St. Johns wort, Klamath weed, goatweed)
A. Toxic principles: A photodynamic pigment called hypericin, a derivative of napthodianthrone, is present in the tiny translucent glands. Toxicosis when animals ingest 1-5% of body weight; fairly stable following drying. May have biological activity in the treatment of depression
B. Mechanism of action: Hypericin is a primary photosensitizer. Passes through liver unchanged; reaches cutaneous circulation and reacts with oxygen and sunlight to yield a highly reactive molecule that reacts with DNA, ribonucleic acid (RNA), proteins, or membranes. Damage to membranes leads to release of lysosomal contents - inflammation results
C. Animals affected: Cattle, sheep, goats, and horses (essentially any grazing animal)
D. Clinical signs and pathologic lesions
1. Lesions are restricted to nonpigmented areas (head, muzzle, ears, teats, udder) and first appear within 24 hours of ingestion. Initially see erythema and edema, followed by varying degrees of ulceration and desquamation. The lesions are often pruritic and secondary bacterial infections are common
2. The cornea and conjunctiva may be affected as well and the animal may become blind
E. Treatment: Keep animals away from sunlight. Antibiotics to prevent or treat skin infections

V. *Vicia villosa* (hairy vetch)
A. Toxic principle: Unknown. Toxicoses only occur when grazing or as silage, not when fed as hay. *Vicia hirsuta, benghalensis, villosa ssp. dasycarpa* have also been implicated
B. Animals affected: Primarily cattle and horses. In cattle, granulomatous disease is more severe in animals over 3 years of age
C. Clinical signs: Three clinical syndromes occur
1. Acute nervous derangement and death following ingestion of the seed
2. Death following subcutaneous swellings of the head, neck, and body, herpetiform eruptions of the oral cavity, purulent nasal discharge, rales, cough, and congestion
3. Systemic granulomatous disease after daily ingestion for at least 2 weeks or more. Often these animals have diarrhea and waste away; fairly high mortality
D. Pathologic lesions
1. Dermatitis (with mild or intense pruritis; starts with the udder, tailhead, and neck and then progresses to include face, trunk, and limbs), conjunctivitis, multiple granulomatous lesions of many internal organs
2. Monocytic, lymphocytic, plasmacytic, and eosinophilic infiltrate with some multinucleated giant cells (type IV hypersensitivity)
E. Treatment: Symptomatic and supportive

VI. *Juglans nigra* (black walnut)
A. Toxic principles and mechanism of action
1. Juglone (a naphthoquinine) is *not* the toxic principle as previously thought
2. All parts of the tree are toxic; laminitis has occurred in horses when bedding contained 5% to 20% black walnut shavings
B. Animals affected: Primarily horses
C. Clinical signs: Within 12 to 24 hours of exposure, see depression, limb edema, laminitis (reluctance to move, shifting weight, elevated digital pulse and hoof temperature)
D. Pathologic lesions: Necrosis of the dermal tips of dorsal primary epidermal laminae
E. Treatment: Remove the shavings and supply soft bedding; treat for laminitis

VII. *Berteroa incana* (hoary alyssum)
A. Toxic principle and mechanism of action: Unknown
B. Clinical Signs: Appear within 18 to 36 hours after ingestion; commonly see fever, lethargy, limb edema (one or all), diarrhea, abdominal discomfort, and laminitis. Generally reported in horses only
C. Treatment: Remove the plant from the diet. AC, symptomatic treatment. Most horses recover uneventfully

TOXICANTS AFFECTING THE OROPHARYNGEAL CAVITY (AND GASTROINTESTINAL (GI) TRACT)

I. Slobbering Disease
A. Source: Fungus *Rhizoctonia leguminicola* infects red clover (*Trifolium pratense*); "black patch." Slaframine is the mycotoxin; grows in cool, wet weather; it is stable and persists; may affect other clovers; alfalfa; other legumes
B. Toxicity and mechanism of action
1. Mimics the action of acetylcholine, with parasympathomimetic effects
2. Cattle, horses, sheep, goats commonly affected
C. Clinical signs: Profuse salivation, mild lacrimation, frequent urination, diarrhea, bloat, stiffness, drop in milk production. Occur within 1 to 3 hours after consumption, subside within 12 to 48 hours if no reexposure
D. Diagnosis: History of feeding moldy clover, slobbering, lack of oral lesions; can confirm with slaframine analysis of feed
E. Treatment: Can remove feed; recover quickly. Do not need atropine

TOXICANTS AFFECTING REPRODUCTION

I. Zearalenone
A. Source: Mycotoxin produced by *Fusarium roseum* or *graminearum* and *moniliforme*. Substrate: Corn, wheat, barley, milo, oats: "Pink ear rot" or "scab". Rare in hay
B. Toxicity and mechanism of action

1. Readily absorbed from GI tract and metabolized to α and β zearalenol
2. Excreted in bile, feces, urine; enterohepatic recirculation occurs
3. Binds to cytosolic receptors for estradiol-17β; Complex migrates to nucleus, binds to estradiol site, initiates RNA synthesis; functions as a weak estrogen
4. Swine and cattle most commonly affected

B. Clinical Signs: Vary according to species, age, and level in diet
1. Swine
 a. Prepubertal females: Hyperestrogenism
 b. Mature sows: Nymphomania, anestrus, pseudopregnancy
 c. Bred sows (7 to 10 days postmating): Early embryonic death, prolonged interestrus intervals
 d. Castrated males: Enlargement of prepuce and nipples
 e. Immature boars: Reduced libido, impaired testicular development
 f. Mature boars: Not affected
2. Cattle: Virgin heifers: Infertility, reduced conception rate, repeat breeding. Cows: Vaginitis, increased vaginal secretions, mammary enlargement

C. Diagnosis based on clinical signs and feed analysis for zearalenone

D. Treatment: Remove contaminated feed; give bentonite, AC, aluminosilicate, binders

II. *Pinus ponderosa, Pinus contorta, Pinus jeffreyi, Pinus radiata, Juniperus communis* (ponderosa pine, western yellow pine, black jack, lodgepole pine, Jeffrey pine, Monterey pine, juniper) (> 20 species of Pinus, Abies, Pseudotsuga, Picea, Cupressus)

A. Toxic principles: Isocupressic acid (abietane diterpene acids) present in needles (green or dry), new-growth branch tips, and bark is responsible for premature parturition. Needles also contain shikimic acid, monomeric phenolics, flavonoids, and tannins

B. Mechanism of action, animals affected, and clinical signs
1. Premature parturition or abortion occurs in the bovine (cattle, buffalo) during late pregnancy. History of ingesting large amounts of pine needles for 3 days or more, usually in winter when normal forage is unavailable
2. Birth may be delayed for 2 to 3 weeks after ingestion; calf is usually born weak with secondary complications (retained fetal membranes, metritis, peritonitis, maternal death)
3. Isocupressic acid reduces blood flow to the gravid uterus; stimulates cortisol release (causes parturition)
4. Preparturient signs: Dullness, depression, weak uterine contractions, incomplete cervical dilation, vulvar swelling, excessive uterine hemorrhage and mucus, "bagging up" (development of udder and milk production)

C. Pathologic lesions: Extensive vasoconstriction of the caruncular vascular bed with necrosis and hemorrhage. May see reduced numbers of binucleate, trophoblastic giant cells in the placentomes, and increased numbers of necrotic luteal cells in corpus luteum

III. *Trifolium subterraneum* (subterranean clover, subclover), *Trifolium pratense* (red clover), and *Medicago spp.* (alfalfa, clover)

A. Toxic principles: Coumesterol in *Medicago* and isoflavone estrogens genistein, daidzein, biochanin-A, and formononetin in *Trifolium*. Other problems, including bloat and photosensitzation have been reported

B. Animals affected: Sheep and cattle

C. Mechanism of action, clinical signs, pathologic lesions
1. Coumesterol: Decreased fertility due to decreased rate of transport of ova in oviduct; temporary. Coumesterol is active in both green and dried plant material
2. Estrogens: Cystic glandular hyperplasia of the cervix (poor sperm penetration); may also see uterine infections, dystocia, prolapse, and reduced milk production
3. Unbred ewes and wethers: Mammary tissue development and occasional lactation. No effect observed in ram fertility

D. Treatment and prevention: Limit access to feed at susceptible times; temporary problem

Supplemental Reading

Gfeller RW, Messonnier SP. *Handbook of Small Animal Toxicology and Poisonings*, 2nd ed. St Louis, 2003, Mosby.

Peterson ME, Talcott PA. *Small Animal Toxicology*, 2nd ed. St Louis, 2005, Saunders.

Plumlee K. *Clinical Veterinary Toxicology.* St Louis, 2004, Mosby.

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11 CHAPTER

Anesthesia

A. Thomas Evans

ANESTHESIA MACHINES AND SYSTEMS

I. Characteristics of a circle anesthesia machine
 A. Conservation of heat and moisture
 B. Absence of abrupt changes in anesthetic depth
 C. Partial pressure of carbon dioxide in arterial gas ($Paco_2$) depends on ventilation, not on fresh gas flow
 D. Disadvantages
 1. Composed of many parts
 2. Greater resistance
 3. Difficult to clean
 4. Not easily portable
 5. Inspired concentration not easily predicted at low gas flows

II. Oxygen cylinders
 A. Color coded: Green in the United States, white in the rest of the world
 B. Full cylinder = 1900 to 2200 psi (oxygen); be careful of high pressure
 C. Pressure reduced via pressure reduction valve or pressure regulator
 D. Attach to machine via a "yoke"; pin index safety system is present
 E. "E" cylinder, 650 to 700 L when full; rented from company
 1. Multiply pounds per square inch (psi) by 0.3 to estimate liters in cylinder
 2. 1 liter/min flow rate = 11 hours (660 min)
 F. Oxygen supports combustion
 G. Open slowly; "righty tighty, lefty loosie"
 H. Change when 100 to 200 psi remain. The anesthesia machines are designed to run at a pressure of 50 psi

III. Oxygen flow meters
 A. Measures gas flow in milliliters or liters per minute
 B. Color coded (green)
 C. Oxygen goes through a graduated glass cylinder with a floating ball or rotor
 D. Oxygen flows should meet or exceed metabolic requirement, which is suggested to be 10 to 15 mL/lb/min (20 to 30 mL/kg/min) for circle system
 E. If using nitrous oxide (N_2O), oxygen flow should be at least 30% of total flow of oxygen and N_2O combined (hence the recommended ratio with nitrous of 2:1 nitrous to oxygen)
 F. 2 to 3 mL/lb/min (4 to 6 mL/kg/min) = metabolic requirement for oxygen

IV. N_2O
 A. Compressed liquid, 750 psi when liquid present
 B. Newer machines have a device that shuts N_2O off if oxygen is not flowing
 C. Analgesic
 D. Relaxant
 E. More potent in humans
 F. Used in 2:1 ratio with oxygen
 G. Second gas effect increases the concentration of the "second gas" administered with nitrous
 H. Diffusion hypoxia (outpouring of nitrous into the alveoli) occurs when patient is removed from the anesthesia machine and immediately allowed to breathe room air (O_2 only 20%)
 I. Gas regulators; pressure reduction valves as follows:
 1. Reduces high pressure in cylinder to 50 psi
 2. Central supply oxygen pressure already reduced to 50 psi

V. Vaporizers
 A. Converts liquid anesthetic (isoflurane, sevoflurane) to a vapor or gas state
 B. Generally, 1.3 to 1.5 × minimum alveolar concentration (MAC) will result in a moderate level of anesthesia; the actual vaporizer setting may have to be slightly higher than this. (MAC is in equilibrium with the partial pressure of anesthetic in the brain)
 C. Expensive, most are agent specific
 D. Should not be tipped over
 E. Precision vaporizers: "Tecs" and "Matics"
 1. Expensive
 2. Used with anesthetics with high vapor pressures
 3. Compensated for temperature, gas flow rate, and back pressure
 4. Dial on top indicates percentage being administered
 5. Out-of-circuit location
 6. Need to be recalibrated

F. Nonprecision
1. Ohio no. 8 (ether 8) is historically used with methoxyflurane
2. This type of vaporizer is rarely used
3. Not temperature compensated
4. Not flow compensated
5. Affected by back pressure
6. Difficult to monitor the concentration of anesthetic
7. Technically difficult to use with non-rebreathing systems
8. Halothane or isoflurane could be used if the wick is removed
9. Inside-the-circle (VIC) location
10. Factors that affect the output of vaporizers:
a. Temperature
b. Carrier gas flow rate; concentration of anesthetic should be increased when using low oxygen flow rates
c. Barometric pressure
d. Back pressure

VI. Unidirectional valves, or "flutter" valves
A. Keep gas flow going in a circle
B. Prevents animal from rebreathing
C. Moisture may cause them to stick
D. May be dislodged during cleaning

VII. Rebreathing or reservoir bag
A. Approximate size should be about 30 mL/lb (equivalent to 6× tidal volume; tidal volume is estimated to be 5 mL/lb)
B. Acts as a reservoir
C. Used to monitor breathing
D. Useful to check position of cuffed endotracheal tube (CETT)
E. Allows "bagging" to prevent atelectasis, removes CO_2
F. Empty bag = too low O_2 flow, too much scavenger, hole in bag

VIII. CO_2 absorption canister
A. Recommended volume = 2× tidal volume
B. Two formulations - soda lime and baralyme
1. Soda lime = 94% calcium hydroxide, 5% sodium hydroxide, and 1% potassium hydroxide
2. Baralyme = 80% calcium hydroxide and 20% barium hydroxide
C. Heat and water produced by the reaction
D. Change absorbent after color changes ½
E. Color change is time limited; check color change after use change if granules are brittle
F. "Channeling" may be a problem

IX. Pop-off valve
A. Normally in the "open" position
B. Allows exit of waste gases to the scavenger
C. Prevents buildup of pressure within the anesthesia system
D. Can be either open or closed in a "closed" system
E. Should be open in a "semiclosed" system
F. Should be either closed or partially closed if you are breathing for the patient

X. Breathing systems
A. Rebreathing
1. Closed
a. Closed system = flow rate of 2 to 3 mL/lb/min (metabolic requirement)
b. Oxygen flow rate is what determines classification
c. No pollution
d. Can estimate anesthetic agent uptake and oxygen consumption
e. Heat and humidity conservation
f. Economy
g. Closer monitoring and more knowledge required
h. Difficult to reanesthetize a patient that wakes up
i. Danger of hypercarbia
j. Buildup of trace toxic materials, such as carbon monoxide, acetone, methane, hydrogen
2. Semiclosed
a. Oxygen flow rate, greater than 2-3 mL/lb/min
b. Some resistance
c. Some dead space
d. The rebreathing tubes are not part of the dead space
e. Length of endotracheal tube (ETT) outside of mouth is considered mechanical dead space

B. Nonrebreathing coaxial system (Bain system)
1. Use oxygen flow rate of 100 mL/lb/min; this recommended rate allows some "rebreathing"; to eliminate all rebreathing, one would need to use a flow rate of 3× the minute ventilation (minute ventilation equals breaths per minute × the tidal volume)
2. The Bain system is used with small patients
3. Little or no dead space
4. Little or no resistance to breathing
5. Do not "flush" a Bain system; sudden large flow may overpressurize and damage lungs
6. Disconnection of the inner limb causes respiratory acidosis

XI. Universal or Mera "F" system
A. A coaxial circle system, with the inspiratory limb contained within the expiratory
B. Less bulky than traditional circle and may offer more heat and humidification of the inspired gases
C. Occult disconnection or kinking of the inner limb causes a huge increase in dead space and respiratory acidosis
1. Does not respond to increased minute ventilation

PREANESTHETIC AGENTS

I. Goals of premedication
A. Reduce stress
B. Provide analgesia
C. Reduce vagal tone
D. Reduce gastric volume
E. Improve induction of anesthesia
F. Improve recovery from anesthesia
G. Decrease salivation
H. Increase gastric pH
I. Amnesia

II. Anticholinergics
 A. Glycopyrrolate, atropine
 B. Parasympatholytic (anticholinergic)
 C. Side effects
 1. Causes tachycardia
 2. Reduced intestinal motility
 3. Mydriasis, reduced tear production
 4. Bronchial dilator
 5. Decreases salivation, which can become a problem in animals that produce a large amount of saliva
 D. Used for intrathoracic cardiovascular cases
 E. Probably contraindicated in horses and ruminants

III. Tranquilizers and sedatives
 A. Acetylpromazine (acepromazine) (a phenothiazine tranquilizer)
 1. Actions
 a. Sedation; sometimes for long periods
 b. Antidysrhythmic
 c. Antiemetic; recommended to be used before opioids
 d. Antihistamine effect
 e. Decreases seizure threshold
 f. Decreases MAC
 g. Little or no analgesic effect but will make opioids more effective
 2. Side effects
 a. Hypotension after large doses
 (1) Small doses typically used in veterinary medicine
 (2) treat overdose (hypotension) with α-agonists, fluids, and atropine (not epinephrine)
 b. Hypothermia
 c. May cause splenic enlargement
 d. Some interference with clotting factors
 e. May cause personality change
 f. Causes priapism in horses
 B. Benzodiazepines: diazepam, midazolam, zolazepam
 1. Effect at γ-aminobutyric acid (GABA) receptor
 2. Diazepam
 a. Intramuscular (IM) absorption not dependable
 b. Passes blood brain barrier
 c. Anticonvulsant
 d. Muscle relaxant
 e. Does not mix with other agents
 3. Midazolam
 a. More potent but shorter acting than diazepam
 b. Water soluble (better for IM injections)
 c. Usually administered with opioids
 d. Little effect on circulatory or pulmonary systems
 e. Can cause excitement when administered alone
 f. The antagonist for diazepam and midazolam is flumazenil
 4. Zolazepam (component of Telazol)
 a. Anticonvulsant
 b. Muscle relaxant
 C. Butyrophenone group of tranquilizers
 1. Droperidol (was a component of Innovar-Vet)
 2. Azaperone (Stresnil)
 3. Butyrophenone tranquilizers produce calming and prevent fighting and cannibalism in pigs (Stresnil)
 D. α-2 Agonists:
 1. Xylazine (short-acting small animal [SA] and long-acting large animal [LA] formulations), detomidine, dexmedetomidine, romifidine
 2. These drugs act by reducing the level of the neurotransmitter norepinephrine centrally and peripherally
 3. Initial hypertension followed by hypotension
 4. Sedation
 5. Relaxation
 6. Analgesia
 7. Adverse effects
 a. Vomiting in small animals
 b. Bradycardia, atrioventricular (AV) block
 c. Sensitization to epinephrine
 d. Respiratory depression in some dogs; dogs may look cyanotic because of peripheral vasoconstriction
 e. May cause bloat in dogs susceptible due to gastrointestinal (GI) stasis
 f. Personality changes
 g. Hyperglycemia; increased urine production
 h. Abortion in cattle during last trimester
 8. Microdose of dexmedetomidine effective (0.5 mcg/lb (1 mcg/kg), intravenous [IV] administration in dogs)
 9. Reversed by yohimbine, tolazoline, atipamezole. Generally, for reversal of medetomidine, use the same volume of atipamezole
 10. Can be absorbed through human skin abrasions (wash off spills)
 E. Opioids (synthetic) and opiates (natural)
 1. These drugs work at various receptors; μ, κ, σ, δ in the spinal cord and brain (all opioids can be combined with a low dose of acepromazine to increase sedation and analgesia)
 2. Reverse opioids with naloxone or nalbuphine
 3. Morphine
 a. Commonly used in dogs, cats, and sometimes horses
 b. Dysphoria
 c. Excitement
 d. Vomiting
 e. Histamine release
 f. Respiratory depression
 g. Bradycardia
 h. Miosis in dogs and primates, mydriasis in cats
 i. Subcutaneous (SC), IM or slow IV administration (over 5 minutes), may cause histamine release and hypotension if administered too rapidly
 4. Meperidine
 a. 1/10 as potent as morphine
 b. Vomiting rare
 c. Histamine release in dogs if given IV
 d. Short duration of action

e. Used for premedication in pediatrics and geriatrics
5. Oxymorphone
a. 5 to 10× as potent as morphine
b. Sedation
c. Analgesia
d. Respiratory depression
e. Bradycardia
f. Vomiting rare
g. Can be administered IV
h. Duration: 1 to 3 hours
6. Hydromorphone
a. 6× as potent as morphine
b. May cause vomiting
c. Sedation
d. Analgesia
e. Duration is 1 to 3 hours
7. Butorphanol
a. Classified as an agonist-antagonist
b. Controlled
c. Little respiratory depression
d. Little cardiovascular depression
e. Sometimes combined with acetylpromazine
f. Rare dysphoria (but does occur)
g. Rare sedation (more common in geriatrics)
h. 1 to 2 hours' duration of action
8. Buprenorphine
a. Another agonist-antagonist, buprenorphine has agonist properties 30× that of morphine
b. No vomiting
c. Some respiratory depression
d. Little cardiovascular depression
e. Used for longer postoperative analgesia needs as duration of action appears clinically to be 4 to 6 hours
f. Buprenorphine is often combined with acetylpromazine to produce profound sedation and analgesia

IV. Dissociative agents
A. Ketamine, tiletamine
B. Low dose provides sedation; high dose provides anesthesia
C. Metabolized by liver (dogs) and excreted through the kidney (cats)
D. Side effects
1. Tachycardia
2. Apneustic breathing
3. Increases intracranial pressure
4. May cause seizures
5. Analgesia (somatic)

INJECTABLE ANESTHETIC AGENTS

I. Ideal injectable agent
A. Rapid onset, recovery
B. Lack of tissue toxicity (what agent has tissue toxicity?)
C. Lack of adverse cardiovascular and respiratory effects
D. Rapid metabolism (even in patients with liver or kidney disease)
E. Provides analgesia
F. Provides muscle relaxation

II. Barbiturates
A. Onset and duration of action dependent of fat solubility, redistribution, and metabolism. Thiopental is fat soluble; pentobarbital is not as fat soluble
B. Thiopental is redistributed; pentobarbital depends on metabolism
C. Breathing is depressed; brief apnea is seen after administration
D. Laryngospasm after thiopental is seen, especially in cats
E. Thiopental causes reduced cardiac output and blood pressure sensitivity to epinephrine is increased (ventricular premature contractions, bigeminy)
F. Be careful in animals with cardiac disease
1. Give more slowly
2. Preoxygenate
3. Give thiopental with lidocaine
G. Reduce dose of thiopental if animal is hypoproteinemic (<3.0 g/dL), acidotic, or extremely thin
H. Sighthounds
1. Tend to overdose at beginning
2. Leads to long recovery as redistribution sites become filled
3. Hepatic metabolism is slower in sighthounds
I. Critically ill animals shunt blood to brain and other internal organs. Thiopental shows greater potency in these animals
J. Perivascular injection alkaline solution: Treat with saline, lidocaine, steroids, antibiotics
K. Excitement during induction or recovery
1. Injection too slow
2. Port on IV line distant from catheter
3. Incorrect dose

III. Cyclohexamines: Ketamine, tiletamine
A. Dissociative anesthesia or catalepsy
B. Animal appears awake but unaware of surroundings
C. Palpebral and laryngeal reflexes remain
D. Swallowing is present but ETT should be used
E. Sensitive to sound
F. Rigid muscles (use sedative or tranquilizer to prevent)
G. Poor visceral analgesia, better somatic analgesia
H. Metabolized by the liver (dog) and excreted by the kidney (cat)
I. Given IV or IM (oral in mean cats). Usually given with diazepam, midazolam, acepromazine, zolazepam, medetomidine, or xylazine
1. Ketamine is usually mixed with diazepam for IV use. Diazepam is not absorbed well IM. Midazolam can be substituted for diazepam
2. Ketamine-xylazine IM in cats can be used for restraint and minor procedures
a. Hypoventilation, hypertension, and decreased CO
b. Possibility of aspiration reduced if xylazine is given a few minutes before the ketamine
3. Tiletamine-zolazepam (Telazol) is used for restraint of mean dogs

a. Can be used SC, IM, and IV in cats; IM and IV in dogs
b. Long recoveries
c. Used as a restraint drug for wildlife
d. Effects similar to ketamine

J. Disadvantages
1. No reversal for ketamine
2. Cardiac effects: Hypertension, tachycardia (not recommended for hyperthyroid or hypertrophic cardiomyopathy [HCM] cats)
3. Respiratory effects: Apneustic breathing
4. Irritating to tissues
5. Increased salivation
6. Increases in cerebrospinal fluid (CSF) and intraocular pressure
7. Eyes remain open, pupil dilated, nystagmus in cats
8. Cats often exhibit hallucination behavior in recovery
9. Temporary blindness

IV. Propofol
A. A substituted phenol (cats are sensitive to phenol compounds)
B. Neutral pH
C. Administer slowly IV
1. Can be mixed with 2.5% thiopental equal amounts
2. Can give by intermittent injection or constant rate infusion (CRI)
D. Disadvantages
1. Paddling or twitching during induction
2. Hypotension and tachycardia or bradycardia
3. Apnea if it is given too rapidly
4. Hemolysis and Heinz body formation in cats (rapid injection and multiple injections)
E. Rapid metabolism and redistribution
F. Premedication recommended
G. Can be used in sighthounds
H. Discard unused portion within 6 hours

V. Etomidate (Amidate)
A. Sedative and hypnotic
B. Short acting, good muscle relaxation, but no analgesia
C. IV in dogs and cats. IV injection may be painful
D. Premedication recommended (diazepam, opioid)
E. Metabolism rapid
F. Advantages
1. Can administer repeated doses
2. Minimal effect on cardiovascular and hepatic systems
3. Works better in sick animals
G. Disadvantages
1. Suppresses adrenal function
2. Nausea, vomiting, and excitement may occur during induction
3. Expensive
H. Open bottles should be discarded

VI. Guaifenesin (glyceryl guaiacolate [GG])
A. A muscle relaxant used in horses and cattle, small ruminants
B. Used in 5% and 10% solutions
C. 10% solutions may cause hemolysis in cattle
D. Perivascular injection may cause a slough
E. Used before ketamine-diazepam or thiopental

INHALATION ANESTHETIC AGENTS

I. Advantages of inhalation anesthesia
A. Easy to change depth of anesthesia
B. Elimination of inhalation agents occurs through the lungs
C. High concentration of oxygen can be delivered
D. Animals are usually intubated

II. Disadvantages
A. Cost of anesthetic machine
B. Slow induction
C. Environmental pollution

III. N_2O, ether (diethyl ether), halogenated compounds (halothane, sevoflurane, isoflurane, methoxyflurane, enflurane, desflurane)
A. Liquid at room temperature
B. Stored inside the vaporizer and evaporated into oxygen and then delivered to the breathing circuit
C. Methoxyflurane, halothane, enflurane, and desflurane are not routinely used in veterinary medicine at present

IV. The goal of inhalation anesthesia is to maintain an optimal and unchanging brain partial pressure as reflected by the alveolar partial pressure. Alveolar partial pressure is important because "the partial pressure of the inhalation anesthetic in the brain is in equilibrium with the partial pressure in the blood which is in equilibrium with the partial pressure in the alveoli."

V. Induction of anesthesia occurs when an anesthetizing partial pressure has been achieved in the brain. The brain can be considered the final site for a series of concentration gradients. Delivered (vaporizer) concentration > anesthesia circuit > inspired > alveolar > arterial > brain

VI. Physical properties of inhalation anesthetics
A. Vapor pressure
1. The pressure a gas exerts on the walls of a closed container at standard temperature and pressure (760 mm Hg at sea level)
2. A measure of volatility, in other words, how easily a liquid evaporates
3. Halothane and isoflurane have relatively high vapor pressures
4. Methoxyflurane (currently not manufactured in the United States) has a low vapor pressure. Sevoflurane is intermediate
5. Vapor pressure at 20° C
a. Halothane, 243 mm Hg
b. Isoflurane, 238 mm Hg
c. Methoxyflurane, 23 mm Hg
d. Diethyl ether, 440 mm Hg
e. Sevoflurane, 157 mm Hg
f. Desflurane, 669 mm Hg
B. Concentration (volumes %) can be converted to vapor pressure or partial pressure by multiplying (volumes % × atmospheric pressure). For example: 2% isoflurane is equal to 15.2 mm Hg (0.02 × 760 mm Hg). Vapor pressure can also be converted to volumes % (vapor pressure divided by atmospheric pressure)

C. Partial pressure
1. A mixture of gases in a container will exert a pressure on the walls of the container
2. The proportion of total pressure from any one gas in the mixture is called the *partial pressure* of that gas
3. Partial pressure equals the volumes % of a gas × total pressure. In air, the oxygen concentration (20%) × total pressure (atm) = the partial pressure of oxygen. 0.20 × 760 mm Hg = 152 mm Hg 152 mm Hg is the partial pressure of oxygen in air at sea level
4. Even though the partial pressures of an anesthetic in different tissues may be at equilibrium, the actual content of anesthetic in those tissues may be different. In other words, the solubility of the anesthetic also plays a role
5. Concentration of a gas: A way of measuring the amount of anesthetic expressed as volumes % of partial pressure (2% isoflurane, 1% halothane, 2 ½% methoxyflurane)

VII. MAC
A. The concentration (or partial pressure) of anesthetic in the alveolus that will keep 50% of the animals anesthetized during a painful stimulus
B. It is a method of comparing potency of inhalation anesthetics
C. MAC reflects the brain partial pressure because the alveolar partial pressure is in equilibrium with the brain
D. MAC relates very closely to the concentration of the inhalant anesthetic required for maintenance anesthesia
E. 1.3× the MAC will keep 99% of the animals anesthetized
F. Combinations of inhaled anesthetics have additive effects of MAC (Table 11-1)

VIII. Solubility
A. Solubility (partition coefficients) of anesthetics in blood and tissues determines the time necessary for equilibration between two phases to occur. Phases refer to "blood phase," "gas phase," or "brain phase"
B. Solubility (of inhalation anesthetics)
1. Blood-gas solubility coefficient determines uptake from the alveoli into the blood and thus the rate of induction of anesthesia
2. Blood will hold more halothane (solubility coefficient = 2.5) than isoflurane (solubility coefficient = 1.5)
3. If an inhalant has a long induction and recovery time, the anesthetic is more than likely very soluble in blood. Conversely, if an inhalant has a short induction and recovery time, the anesthetic is more than likely relatively insoluble (Table 11-2)

IX. Delivery of gases from breathing circuit to alveoli depends on minute ventilation
A. Increases in minute ventilation increase delivery
B. Decreases in minute ventilation slow delivery
1. Airway obstruction
2. Increased anatomic dead space

X. Transfer of gases from alveoli to blood depends on the following:
A. Pulmonary blood flow
B. Matching of ventilation to perfusion in the lung
C. Shunt
D. Concentration of anesthetic in blood

XI. Transfer of anesthetics from the blood to tissues depends on the following:
A. Tissue blood flow
B. Tissue/blood solubility coefficient
C. Duration of exposure to the anesthetic

XII. Factors that affect the concentration of anesthetics in the lungs
A. An increase in ventilation will increase alveolar concentration
B. A decrease in ventilation will lower alveolar concentration
C. Animals with low cardiac output (shock) can also develop deep anesthesia
D. Circulatory depression produces a positive feedback

XIII. The rate of induction of anesthesia is determined by the rate of rise of the alveolar partial pressure. The following factors determine the rate of rise of alveolar concentration:
A. Alveolar ventilation
B. The inspired concentration: If you use a higher concentration of anesthetic, the alveolar concentration will rise faster. You can decrease some of the effects of tissue uptake by taking advantage of this "concentration effect"

XIV. Factors that determine tissue uptake of anesthetic:
A. Solubility
B. Cardiac output
C. Alveolar to venous gradient

XV. Recovery
A. Recovery from anesthesia reflects reversal of the concentration gradients established during

Table 11-1 Minimum Alveolar Anesthetic (MAC) Values for Some Common Species (%)

	Halothane	Isoflurane	Sevoflurane
Cat	1.1	1.6	2.6
Dog	0.9	1.3	2.3
Horse	0.9	1.3	2.3
Pig	0.9	1.4	2.6

Table 11-2 Solubility (Partition Coefficients) of Popular Anesthetics (37°C)

Anesthetic	Blood/Gas Coefficient
Halothane	2.5
Isoflurane	1.5
Sevoflurane	0.68

induction of anesthesia. The rate of recovery may be influenced by the duration of prior administration and the metabolism of the inhaled anesthetic
B. Recovery is fastest following the short duration administration of inhaled anesthetics that are poorly soluble in blood and tissues

XVI. N_2O
A. Transfer of N_2O to closed gas spaces: N_2O will move into air filled spaces such as the gut, air sinuses, middle ear. Air introduced into the body will also be affected. These air-filled spaces will increase in volume or pressure (pneumothorax)
B. Diffusion hypoxia: After abruptly discontinuing the use of N_2O, there will be an outpouring of N_2O into the lung from the blood, resulting a reduction in available oxygen
C. Second gas effect: The rapid uptake of N_2O increases effective minute ventilation and the rate of uptake of concomitantly inhaled gases (isoflurane, oxygen)
D. The uptake of nitrous also contracts the alveoli concentrating the remaining gases

MONITORING THE ANESTHETIZED PATIENT (FROM THE LATIN *MONERE,* WHICH MEANS "TO WARN")

I. Qualitative assessment respiratory system. Some terms concerning breathing patterns (*pnoia* = from the Greek "breath") follow:
A. Hyperventilation = a $Paco_2$ level in the arterial blood lower than 40 mm Hg
B. Hypoventilation = a $Paco_2$ level in the arterial blood higher than 40 mm Hg
C. Tachypnea = a fast breathing rate
D. Bradypnea = a regular slow breathing rate
E. Hyperpnea = fast or deep respiration
F. Hypopnea = slow or shallow breathing
G. Biot's respiration = several breaths in a row followed by a period of apnea, repeating
H. Cheyne-Stokes respirations = breathing with increasing rate and depth followed by decreasing rate and depth followed by apnea, repeating pattern

II. Respiratory rate and depth
A. Normal rate during anesthesia in dogs is 8 to 20 breaths per minute. Toy breeds and obese animals may breathe at a faster rate
B. Inhalation anesthetics tend to increase the breathing rate (but decrease the tidal volume)
C. Normal tidal volume = 5 mL/lb (10 mL/kg)
D. Breathing progresses from thoracic and abdominal to all abdominal to gasping as anesthesia deepens

III. Circulatory system
A. Mucous membrane color
1. Should be "pink"
2. May be bright red when carbon dioxide is high (local tissue vasodilation)
3. Cyanosis indicates some problem with oxygen delivery; this must be corrected immediately!
4. Pale mucous membranes indicate poor perfusion of tissues
5. Check mucous membranes of the mouth, eyelids, footpads, ears, prepuce, vulva

B. Capillary refill time (CRT)
1. Should be less than 2 seconds
2. Usually poor CRT after α-2 agent
3. Slow CRT may reflect low blood pressure
4. Present after death

C. Heart rate and rhythm
1. Acceptable rate for dogs is greater than 60 beats per minute (beats/min). Some large-breed dogs, however, are okay at a slower rate (i.e., in the 50s) during anesthesia
2. Acceptable rate for cats is 100 beats/min; 80 to 90 beats/min might be acceptable before surgery starting if color, jaw tone, pulse are acceptable
3. High range for dogs is 150 to 160 beats/min; for cats, 180 to 200 beats/min
4. Normal heart rate for horses during anesthesia is 26 to 40 beats/min
5. Heart rate can be monitored by electrocardiogram (ECG), using the esophageal stethoscope, counting pulse rate, pulse oximeter, or hand palpating the chest

D. Pulse strength and blood pressure
1. A superficial pulse can be palpated in a number of areas
a. Common sites include radial, femoral, dorsal pedal, lingual, metacarpal, recurrent metatarsal, palatine arteries
b. The lingual and the metacarpal are usually accessible to the anesthetist from the front of the surgery table
2. The pulse strength is related to the pulse pressure. The pulse pressure is the difference between the systolic pressure and the diastolic pressure
a. Keep the mean pressure [MAP = diastolic pressure + (systolic pressure − diastolic pressure)/3] above 60 mm Hg for dogs and cats and above 70 mm Hg for horses
b. A low blood pressure (hypotension) may be due to deep anesthesia, vasodilation, blood loss, dehydration, obstruction of blood flow, or a failing heart
c. A high blood pressure (hypertension) may be due to surgical stimulation, light anesthesia, excessive fluid administration, thyroid tumor, adrenal tumor (pheochromocytoma) or administration of a drug that causes vasoconstriction (epinephrine, ephedrine, phenylephrine)

E. Indirect blood pressure equipment: Doppler, oscillometric
1. Use a correction factor of 14 mm Hg added to the value obtained by the Doppler in cats
2. Cuff width should be approximately 40% of the circumference of the leg. A cuff width less than the circumference will give readings higher than the actual pressure
3. The oscillometric monitor does not work well in cats because of the small size of the leg and arteries

IV. Eye position, palpebral reflex
 A. The eye position tends to be centered when the patient is deep or light. Therefore, you would like the eye to be rotated down and medially during maintenance anesthesia
 B. Palpebral reflex is tested by tapping the medial or lateral canthus or by brushing the eye lashes. Usually disappears about the time surgical anesthesia begins
V. Thermoregulation
 A. Anesthetized animal body temperature falls during anesthesia tranquilizers and anesthetics prevent shivering
 B. Hypothermia lowers MAC value, slows metabolism of drugs; use thermometer to document
 C. Prevention
 1. Warm IV fluids
 2. Low oxygen flow rates
 3. Warm water heating blanket
 4. Bair hugger
 5. Insulate operating table
 6. Warm environment
 7. Dry the animal
VI. Catheter maintenance and fluid administration
 A. Keep catheter patent; sometimes this is difficult owing to position under the drapes
 B. Monitor fluid administration (usual rate = 5 ml/lb per hour or 10 mL/kg per hour). Use burette if warranted
VII. Blood loss
 A. Sometimes difficult to gauge
 1. Use suction devices to aspirate blood from the surgical site, but the canister may also contain saline, so it is an educated guess as to how much blood has been lost
 2. Saturated sponges contain 5 or 6 (3×3) up to 10 (4×4) mL of blood
 B. A healthy animal can lose up to 15% of its blood volume without major problems. One way of estimating blood volume is to take 8% of the animal's weight in kilograms
 C. Replacement
 1. Blood loss can be replaced with a balanced electrolyte at 3× the volume of blood loss. Three times the volume is used because only a portion of the balanced electrolyte remains in the vascular compartment
 2. Blood loss can be replaced with whole blood at a 1:1 ratio because the blood stays in the vascular compartment
 3. Other high-molecular-weight solutions such as hetastarch can also be used, but a smaller volume is needed
VIII. Quantitative assessment of anesthesia
 A. Pulse oximetry
 1. Measures the amount of oxygen bound to hemoglobin (percentage of total capacity)
 2. Sensor (usually a human earclip) is placed across a thin tissue (usually the tongue)
 a. The sensor shines near infrared and infrared light of different wave lengths through the tissue
 b. The light is absorbed differently, depending on whether the hemoglobin is saturated with oxygen (oxyhemoglobin) or not (deoxyhemoglobin)
 c. The percent of saturation of hemoglobin is then displayed as a numeric value on the monitor
 3. Accuracy is affected by bright lights, abnormal hemoglobins, movement of the patient, various dyes, vasoconstriction, thickness of hair coat, color of hair coat
 4. Keep the saturation 90% or greater
 a. Pulse oximetry will not warn of a developing hypoxemia when the Pa_{O_2} is greater than 60 mm Hg
 b. 90% saturation of hemoglobin (arterial blood) with oxygen equates to a Pa_{O_2} of 60 mm Hg
 5. Factors that affect how easily oxygen is released from the hemoglobin
 a. Low pH (acidosis), high temperature, high CO_2 (respiratory acidosis), and increased 2-3 diphosphoglycerate make it easier for oxygen to be released from hemoglobin
 b. When the curve shifts to the right, oxygen is released from the hemoglobin easier
 c. When the curve shifts to the left, oxygen is not released as easy (held more tightly) by hemoglobin
 6. Venous blood normally has a hemoglobin saturation of 75% and a PvO_2 of 40 mm Hg
 B. Capnography
 1. Capnography is a method of monitoring the amount of CO_2 in the air that is breathed in and out by the patient
 2. CO_2 is measured by collecting the gas and transporting it via a tube to the machine (side stream) or measuring the CO_2 via a sensor in an airway adaptor (mainstream)
 3. The highest part of the curve is the end tidal CO_2
 4. If the curve fails to go to the bottom (to the baseline), it is termed *rebreathing*
 5. Low values (<40 mm Hg) are due to overzealous ventilation, hypothermia, open thoracic surgery, tube in the esophagus or cardiac arrest (no CO_2 would be measured during a cardiac arrest)
 6. High values (> 40 mm Hg) are due to hypoventilation, hyperthermia, effects of premeds and anesthesia
 C. ECG
 1. Monitors electrical rhythm of the heart
 2. During anesthesia the ECG is used primarily for detection of dysrhythmias and for monitoring heart rate
 3. There are many causes of artifacts in the ECG, including patient movement, movement of the leads, poor contact with the skin, cautery
IX. Reflexes
 A. Swallowing reflex
 1. Present during light anesthesia

2. Generally wait until the swallowing reflex returns before removing the ETT

B. Pedal reflex
1. Obtained by pinching or squeezing the toe or footpad
2. Not present during inhalation anesthesia
3. Used in lab animals during pentobarbital anesthesia
4. Animals may have this reflex but not be aware of pain

C. Ear-flick reflex
1. Used primarily in cats
2. Present at all levels of anesthesia
3. Not a good reflex to judge the depth of anesthesia

D. Corneal reflex
1. Can be elicited by squirting eye washing solution into the eye
2. Present until deep levels of anesthesia are attained

E. Laryngeal reflex
1. Present during light anesthesia
2. Dogs generally do not have a strong laryngeal reflex; however, cats have a strong one, especially after thiopental, thus the use of lidocaine on the larynx before attempting to intubate

X. Judging the depth of anesthesia
A. In its simplest concept, the anesthetist needs to keep the animal from moving or sensing pain during the procedure
B. Learn to assess several parameters at the same time to get an overall picture of anesthetic depth
1. Check jaw tone
2. Look at the eye position
3. Check the breathing pattern
4. Evaluate the blood pressure
5. Count the heart rate
6. Is there any response to surgery?
7. What does the pulse feel like?
8. What is the color of the mucous membranes? Pink? Pale?
9. What is the CRT?
10. Check the vaporizer setting compared with the MAC value to see whether it makes sense after evaluation of the animal's anesthetic depth
11. Sometimes, even though the patient seems anesthetized, movement occurs when the type or degree of stimulation changes
12. Pinch toe to see whether there is any response

C. Have "top-off dose" of injectable agent available and ready to inject
D. Do not allow the patient to remove the ETT

PAIN

I. Definitions
A. Pain: An unpleasant sensory or emotional experience
B. Analgesia: The absence of pain achieved through drugs or other means
C. Acute pain: Abrupt onset and short duration of pain
D. Chronic pain: Slow onset and long duration (cancer pain)
E. Referred pain: Pain from a body part felt in a different part of the body
F. Hyperesthesia: Increased sensitivity to a stimulus
G. Neuropathic pain: Pain from physical damage to a nerve
H. Allodynia: Pain resulting from a stimulus that does not normally provoke pain
I. Nociceptor: The afferent nerve ending that is sensitive to a noxious stimulus
J. Nociception: Reception, conduction, and central nervous processing of nerve signals generated by the stimulation of nociceptors
K. Preemptive analgesia: Establishment of analgesia before the onset of pain
L. Somatic pain: Sharp, stabbing, well-localized pain typically arising from skin, skeletal muscle, and the peritoneum
M. Visceral pain: Pain arising from visceral tissues that is not well located, radiates, and is often rhythmic

II. "Nociceptors" detect
A. Heat, ischemia, distention, mechanical injury
B. Chemicals released: Prostaglandins, leucotrienes, bradykinin, proteolytic enzymes, histamine, potassium ion, and serotonin

III. Why treat pain?
A. What is painful for humans is probably painful for animals
B. Most animal owners expect their pets will be treated for pain
C. Inhalants and tranquilizers do not have analgesic properties
D. Poor recoveries from anesthesia if animal is having pain
E. Pain is not protective in the postoperative period
F. Pain can lead to the following:
1. Increased fear and anxiety
2. Poor appetite
3. Increased risk of infection
4. Lower survival rate with major illness

IV. Physiology
A. Two types of neurons that transmit pain impulses
1. A δ-fibers: Sharp pain
2. C fibers: Dull, throbbing pain that is difficult to localize

B. The pain impulses are transmitted to the dorsal horn of the spinal cord, where they are either suppressed or augmented
C. The pain is then transmitted to the brain where the perception of pain occurs

V. Monitoring pain
A. Intensity of pain depends on the surgical procedure; severe pain occurs after declawing, orthopedic procedures, amputations, ear ablations
B. Amount of pain depends somewhat on the individual animal
1. There appears to be a five-fold difference in the amount of analgesic required in people and that required in animals

2. Collies, malamutes, and huskies appear to have little tolerance for pain
C. Pain appears to be strongest in the first 24 hours after surgery
D. Animals hide pain from humans

VI. Signs of pain
A. Vocalization
B. Facial expression
C. Posture
D. Amount of activity
E. Attitude
F. Appetite
G. Urinary and bowel habits
H. Lack of grooming
I. Response to palpation
J. Physiologic changes such as heart rate, breathing rate, pupil size, pale mucous membranes
K. Laboratory findings of increased cortisol, epinephrine

VII. Methods of controlling pain
A. Some analgesia from endorphins, leu-enkephalin, dynorphin, acupuncture
B. Transcutaneous electric nerve stimulation (TENS)
C. Nonpharmacologic pain control
1. Good nursing care
2. Opportunity for urination and defecation
3. Cold or heat packs
D. Pharmacologic pain control
1. More than one class of analgesic may be the best protocol (balanced analgesia)
a. Opioid + nonsteroidal antiinflammatory drug (NSAID)
b. The goal is to have the patient sleep and move around comfortably
2. Methods of delivery injection (including epidural, intraarticular), oral, transdermal
3. Administer pain drugs before the pain occurs (preemptive analgesia) to prevent "windup," or the buildup of chemical mediators within the spinal cord
4. Opioids: Effective against "sore" or "achy" pain but not so effective for sharp pain
a. Morphine, hydromorphone, oxymorphone, Demerol (meperidine), fentanyl, butorphanol (mild to moderate pain, visceral pain), buprenorphine (oral in cats)
b. Intraarticular morphine: Instilled in the joint immediately before or after closure of the joint capsule
c. Epidural morphine
(1) Contraindications include septicemia, skin infections, neurologic disorders, bleeding disorders
(2) Complications include urinary retention, pruritus, respiratory depression
d. Transdermal morphine fentanyl patch
(1) Several hours' delay before blood level is achieved
(2) Theoretically, butorphanol may reverse the fentanyl (do not use concurrently)
(3) Do not use under heat source
5. NSAIDs
a. Aspirin, acetaminophen, ibuprofen, flunixin, ketoprofen, ketorolac, carprofen, meloxicam
b. Effective against somatic pain and, depending on the drug, visceral pain
c. Antiinflammatory, antipyretic
d. They inhibit prostaglandin synthesis
e. Effective in 30 to 60 minutes
f. Several species differences in their effects (Tylenol toxicity in cats)
g. Toxicity
(1) Stomach ulceration
(2) Renal toxicity
(3) Prolonged bleeding times
(4) May antagonize cardiovascular drugs such as enalapril
(5) Liver failure in some dogs has been reported
6. Combinations
a. Tylenol-codeine: 10 mg/kg acetaminophen/0.5 to 1 mg/kg codeine every 6 to 12 hours (do not give to cats)
b. Morphine at the time of surgery and then ketoprofen at the end of surgery
c. Acepromazine + morphine or other opioid
d. Local analgesics lidocaine, bupivacaine: Do not exceed 2 mg/kg in dogs and 0.5 to 1 mg/kg in cats with bupivacaine
e. Splash blocks, intraarticular, epidural, nerve blocks, topical (EMLA [eutectic mixture of local anesthetics] cream)
7. α-2 agonist: Medetomidine
8. Dissociative: Ketamine
9. Total intravenous anesthesia (IVA)
a. Fentanyl
b. Lidocaine
c. Morphine
d. Ketamine
e. MLK (morphine, lidocaine, ketamine)
f. Propofol

Supplemental Reading

Greene SA. *Veterinary Anesthesia and Pain Management Secrets.* Philadelphia, 2002, Hanley & Belfus.

Muir WW, Hubbell JAE. *Handbook of Veterinary Anesthesia,* 4th ed. St Louis, 2007, Mosby.

Thurmon JC, Tranquilli WJ, Benson GJ. *Essentials of Small Animal Anesthesia & Analgesia.* Baltimore, 1999, Lippincott Williams & Wilkins.

Cardiovascular Disorders

12 CHAPTER

Ashley B. Saunders

CARDIOVASCULAR PHYSIOLOGY DEFINITIONS

I. Afterload: The force or tension on the ventricular myocardium during contraction
II. Preload: The volume of blood present in the ventricle at the end of diastole
III. Chronotropy: Heart rate
 A. *Positive chronotropy* designates an increase in heart rate
 B. *Negative chronotropy* designates a decrease in heart rate
IV. Inotropy: Myocardial contractility
 A. *Positive inotropy* designates an increase in contractility
 B. *Negative inotropy* designates a decrease in contractility
V. Systole: Contraction of the heart chambers
VI. Diastole: Period of relaxation of the heart chambers
VII. Cardiac output: The combination of stroke volume and heart rate
VIII. Systemic vascular resistance: Resistance to blood flow through the systemic arterioles
IX. Blood pressure: The combination of cardiac output and systemic vascular resistance
X. Eccentric hypertrophy: Dilated atrial or ventricular chambers with normal to decreased wall thickness caused by a volume overload. Examples of heart diseases that result in eccentric hypertrophy include the following:
 A. Dilated cardiomyopathy
 B. Valvular endocardiosis
 C. Patent ductus arteriosus (PDA)
 D. Ventricular septal defect
 E. Atrial septal defect (ASD)
XI. Concentric hypertrophy: Ventricular wall thickening caused by a pressure overload. Examples of heart diseases that result in concentric hypertrophy include the following:
 A. Systemic hypertension
 B. Pulmonary hypertension
 C. Pulmonic stenosis
 D. Aortic stenosis
XII. Heart failure: Occurs when the hearts ability to supply adequate blood flow is reduced
 A. Congestive: Occurs when reduced cardiac function results in elevated venous pressures and fluid accumulates in organs or body cavities
 B. Backward: Congestive
 C. Forward: Reduced cardiac output
 D. Left-sided: Results in pulmonary edema
 E. Right-sided: Results in hepatomegaly, ascites, pleural effusion, pericardial effusion
 F. Neuroendocrine consequences of heart failure
 1. Activation of the renin angiotensin aldosterone system (RAAS): A decrease in cardiac output is detected by the kidneys. Renin is released and converts angiotensinogen to angiotensin I in the liver. Angiotensin I is converted to angiotensin II in the lungs. Angiotensin II stimulates constriction of vascular smooth muscle, and increased blood volume. Angiotensin II stimulates aldosterone, which leads to increased sodium chloride retention, and increased blood volume
 2. Activation of the sympathetic nervous system. Norepinephrine levels increase in response to a decrease in cardiac output and results in tachycardia and vasoconstriction

DIAGNOSTIC TESTS

I. Echocardiography: Ultrasound of the heart used to evaluate structure and function
II. Electrocardiography: Records the electrical activity of the heart for analysis of heart rate and rhythm, conduction abnormalities, and chamber enlargement patterns
III. Holter monitor: Records an electrocardiogram (ECG) over an extended period
IV. Thoracic radiographs: Used to evaluate heart size and shape, to assess pulmonary and mediastinal structures, and to evaluate for congestive heart failure (CHF)
V. Blood pressure: Systolic; mean and diastolic systemic arterial pressure can be measured invasively (direct) or noninvasively (indirect)
VI. Cardiac catheterization and angiography: Catheters placed into peripheral vessels are used to evaluate hemodynamics and to perform contrast studies of the heart and vessels
VII. Nuclear cardiology: First-pass nuclear angiocardiography studies assess the direction and magnitude of shunts, and gated radionuclide studies evaluate ventricular function

Table 12-1 Clinical Characteristics of the Most Common Congenital Heart Defects in Dogs

Defect	Murmur Location	Murmur Timing	Pulse Quality
Patent ductus arteriosus	Left base	Continuous	Bounding
Pulmonic stenosis	Left base	Systolic	Normal
Subaortic stenosis	Left base	Systolic	Normal to decreased

CONGENITAL HEART DISEASE

I. The most common congenital heart diseases in dogs are PDA, subaortic stenosis, and pulmonic stenosis
II. The most common congenital heart diseases in cats are septal defects (ASD, ventricular septal defect, endocardial cushion defect) and atrioventricular valvular dysplasia
III. Most common defects resulting in cyanosis
 A. Tetralogy of Fallot
 B. Right-to-left shunting PDA. Creates differential cyanosis, cyanosis of the caudal mucous membranes
 C. Right-to-left shunting ventricular septal defect
IV. Aortic stenosis
 A. Most often occurs as a result of a ridge or ring of tissue below the aortic valve (subvalvular)
 B. Severity can increase until a dog reaches mature body weight
 C. Heritable
 D. Common breeds: Newfoundland, golden retriever, Rottweiler, German shepherd, boxer, bull terrier
 E. Clinical signs: May be normal; exercise intolerance, lethargy, syncope, cough, dyspnea, sudden death
 F. Physical examination (Table 12-1)
 1. Systolic left basilar murmur
 2. Diastolic left basilar murmur
 3. Normal to weak pulse quality
 4. Dyspnea
 G. Diagnosis
 1. Echocardiogram
 a. Left ventricular hypertrophy
 b. Left atrial enlargement
 c. Subvalvular narrowing
 d. Poststenotic dilation of aorta
 e. Thickened aortic valve leaflets
 f. Aortic regurgitation
 g. Elevated transaortic velocities
 2. Electrocardiography
 a. Tall R waves in lead II suggestive of left ventricular enlargement
 b. Wide P wave in lead II suggestive of left atrial enlargement
 c. ST segment depression
 d. Ventricular arrhythmias
 3. Thoracic radiographs (Figure 12-1)
 a. Normal in dogs with mild disease
 b. Left ventricular enlargement
 c. Left atrial enlargement
 d. Poststenotic dilation of aorta

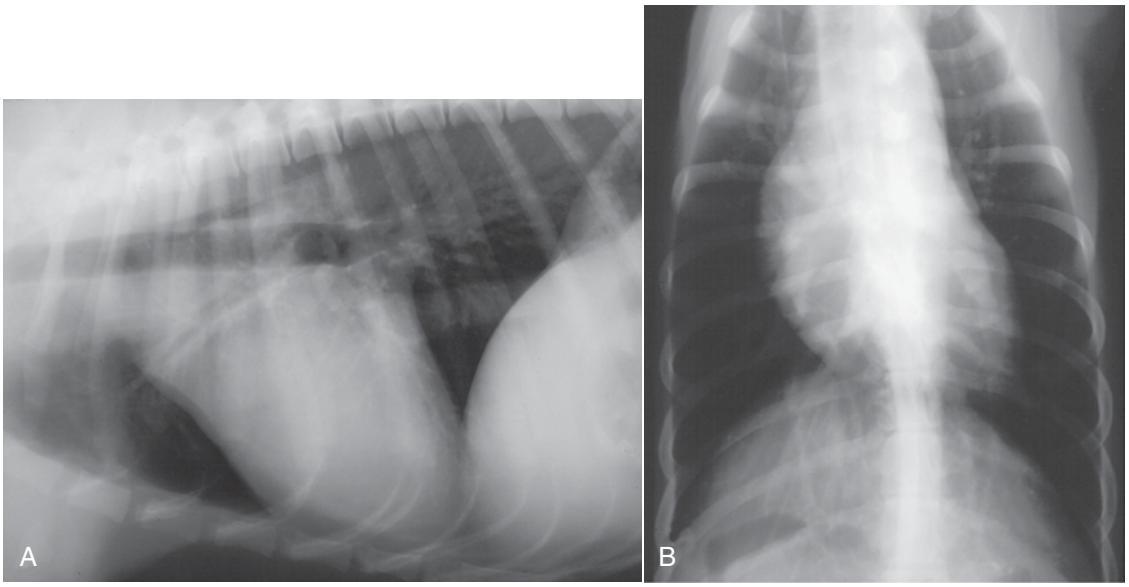


Figure 12-1 Lateral **(A)** and dorsoventral **(B)** radiographs from a young dog with subaortic stenosis. Prominent bulge in the cranial waist on the lateral view and widening of the cranial mediastinum on the dorsoventral view are consistent with poststenotic dilatation of the ascending aorta. (From Ettinger, SJ, Feldman, EC. *Textbook of Veterinary Internal Medicine*, 2-Vol Set, 6th ed. Philadelphia, 2004, Saunders.)

H. Treatment
1. Balloon valvuloplasty
 a. Variable success rate
 b. No additional benefit compared with β-blocker therapy alone
2. Surgery
 a. Resection of subvalvular lesion and replacement with patch graft
 b. High degree of difficulty
 c. Requires special equipment
 d. Costly
 e. Not readily available
3. Medical management
 a. β-Blocker therapy
 b. Antibiotic therapy to prevent valvular endocarditis during periods of bacteremia
 c. CHF
 (1) Oxygen
 (2) Diuretics
 (3) Nitroglycerin ointment
 (4) Angiotensin-converting enzyme (ACE) inhibitor

I. Prognosis
1. Mild: Favorable; rarely develop clinical signs
2. Moderate: Favorable; may develop clinical signs
3. Severe: Develop clinical signs, shortened life span, risk of sudden death

V. ASD
A. Occurs in dogs and cats
B. Typically shunts left to right
C. Common breeds: Boxer, standard poodle
D. Clinical signs: May be normal; exercise intolerance, lethargy, syncope, right heart-sided heart failure with large defects, ascites
E. Physical examination
1. Systolic left basilar murmur
2. Split second heart sound
3. Normal pulse quality
4. Right-sided heart failure with large defects: Ascites, jugular venous distension, positive hepatojugular reflex

F. Diagnosis
1. Echocardiogram
 a. Right ventricular enlargement
 b. Right atrial enlargement
 c. ASD
2. Electrocardiography
 a. Deep S waves in leads I, II, III, aV_f are suggestive of right ventricular enlargement
 b. Right axis deviation
 c. Tall P waves in lead II suggestive of right atrial enlargement
3. Thoracic radiographs
 a. Normal in dogs with mild disease
 b. Right atrial enlargement
 c. Right ventricular enlargement
 d. Main pulmonary artery dilation
 e. Pleural effusion

G. Treatment
1. Interventional catheterization. Device used to close large ASDs
2. Surgery
 a. Patch graft
 b. High degree of difficulty
 c. Requires special equipment
 d. Costly
 e. Not readily available
3. Medical management. Congestive right heart failure
 a. Oxygen
 b. Diuretics
 c. Positive inotropic support
 d. ACE inhibitor
 e. Pleurocentesis
 f. Abdominocentesis

H. Prognosis
1. Small defects: Favorable; rarely develop clinical signs
2. Moderate to large defects: Develop clinical signs, shortened life span without defect closure

VI. PDA
A. Common congenital heart defect in dogs
B. More common in females
C. Heritable
D. Results from a congenital lack of ductal smooth muscle
E. Typically left to right shunting
F. Common breeds: Miniature poodle, Maltese, German shepherd, Yorkshire terrier, Shetland sheepdog, collie, Pomeranian, Labrador retriever, bichon frise
G. Clinical signs: May be normal; exercise intolerance, lethargy, cough, dyspnea
H. Physical examination
1. Continuous left basilar murmur
2. Systolic left apical murmur of mitral regurgitation
3. Increased (hyperkinetic) pulse quality results from a large difference in systolic and diastolic pulse pressure
4. Dyspnea

I. Diagnosis
1. Echocardiogram
 a. Left ventricular enlargement
 b. Left atrial enlargement
 c. Continuous color flow within the main pulmonary artery
 d. Visualization of the PDA. Typically funnel shaped with narrowing at the pulmonary artery side
 e. Mitral regurgitation
2. Electrocardiography
 a. Tall R waves in lead II suggestive of left ventricular enlargement
 b. Wide P waves in lead II suggestive of left atrial enlargement
3. Thoracic radiographs
 a. Normal in dogs with mild disease
 b. Left atrial enlargement
 c. Left ventricular enlargement
 d. Aneurysmal bulge of descending aorta
 e. Pulmonary overcirculation
 f. Pulmonary edema
4. Blood pressure
 a. Normal systolic
 b. Decreased diastolic

J. Treatment
1. Interventional catheterization: Device implantation (coil, vascular plug, ductal occluder)
2. Surgery. Ligation
3. Medical management
a. CHF
(1) Oxygen
(2) Diuretics
(3) Positive inotropic support
(4) Nitroglycerin ointment
(5) ACE inhibitor

K. Prognosis
1. Small PDA: Favorable, might not develop clinical signs
2. Moderate to large PDA: Develop clinical signs, favorable with ductal occlusion-ligation; shortened life span without treatment

L. Right-to-left shunting PDA
1. Attributed to increased pulmonary vascular resistance
2. Patients develop hypoxemia, exercise intolerance, collapse, tachypnea, dyspnea, ascites
3. Polycythemia results from hypoxemia and is managed with phlebotomy or hydroxyurea
4. PDA closure is contraindicated and will result in severe hypoxemia and death
5. Prognosis is poor

VII. Pulmonic stenosis
A. Valvular pulmonic stenosis is a common congenital heart disease in dogs
B. Severity can increase until a dog reaches mature body weight
C. Occasionally, an aberrant left coronary artery encircles the right ventricular outflow tract and pulmonic valve causing pulmonic stenosis. Occurs most often in the English bulldog and boxer
D. Heritable
E. Common breeds: English bulldog, West Highland white terrier, boxer, Chihuahua, mastiff, beagle
F. Clinical signs: May be normal; exercise intolerance, lethargy, syncope, ascites, sudden death
G. Physical examination
1. Systolic left basilar murmur
2. Diastolic left basilar murmur with significant pulmonic valvular regurgitation
3. Normal pulse quality
4. Ascites
5. Jugular venous distension
6. Positive hepatojugular reflex

H. Diagnosis
1. Echocardiogram
a. Right ventricular hypertrophy
b. Interventricular septal flattening
c. Right atrial enlargement
d. Poststenotic dilation of main pulmonary artery
e. Thickened pulmonic valve leaflets
f. Restricted motion of pulmonic valve leaflets
g. Pulmonic regurgitation
h. Elevated peak transpulmonic velocities
i. Hypoplastic pulmonic valve annulus
j. Aberrant coronary artery
2. Electrocardiography
a. Deep S waves in leads I, II, III, aV_f suggestive of right ventricular enlargement
b. Right axis deviation
c. Tall P waves in lead II suggestive of right atrial enlargement
3. Thoracic radiographs (Figure 12-2)
a. Normal in dogs with mild disease
b. Right ventricular enlargement
c. Right atrial enlargement

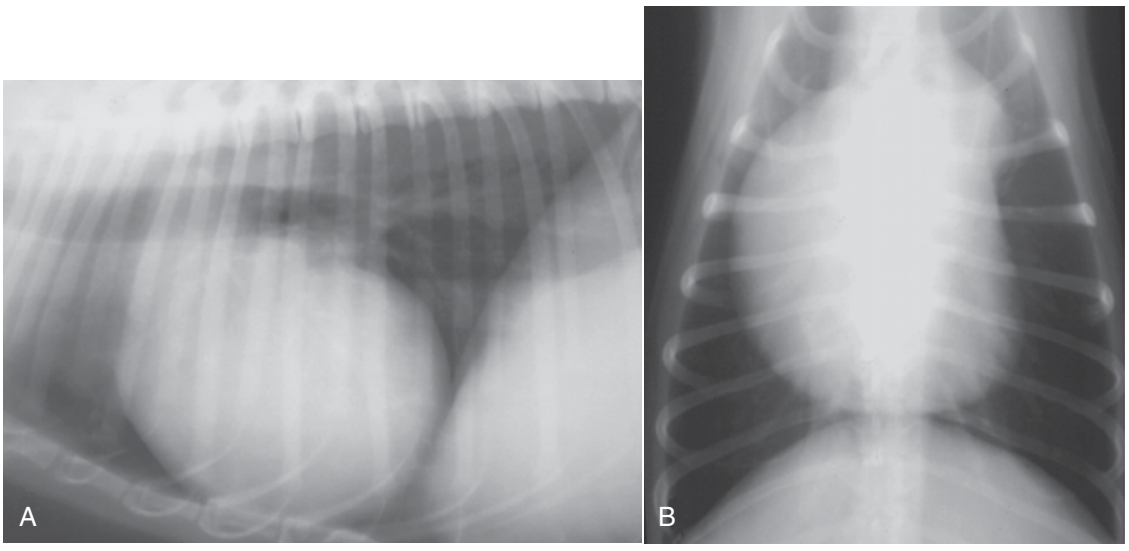


Figure 12-2 Lateral **(A)** and dorsoventral **(B)** thoracic radiographs from a dog with pulmonic stenosis. Rounding of the sternal border and a bulge in the cranial waist of the heart can be seen in the lateral view. Right heart enlargement and a bulge in the main pulmonary artery segment are seen in the dorsoventral view. Pulmonary vessels are diminished even in the absence of a right-to-left shunt. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine*: 2-Vol Set, 6th ed. Philadelphia, 2004, Saunders.)

d. Poststenotic dilation of main pulmonary artery
e. Enlarged caudal vena cava

I. Treatment
1. Balloon valvuloplasty
a. For valvular pulmonic stenosis
b. Prognosis improved if pressure gradient is reduced to mild
2. Surgery
a. Resection of stenotic area and replacement with a patch graft
b. Conduit around stenosis, especially if aberrant coronary artery
c. High degree of difficulty
d. Requires special equipment
e. Costly
f. Not readily available
3. Medical management
a. β-Blocker therapy
b. Congestive right-sided heart failure
(1) Oxygen
(2) Diuretics
(3) ACE inhibitor
(4) Pleurocentesis
(5) Abdominocentesis

J. Prognosis
1. Mild: Favorable; rarely develop clinical signs
2. Moderate: Favorable; may develop clinical signs
3. Severe: Develop clinical signs; shortened life span, risk of sudden death

VIII. Tetralogy of Fallot
A. Characterized by a ventricular septal defect, pulmonic stenosis, overriding aorta and right ventricular hypertrophy
B. Pulmonic stenosis creates an obstruction to blood flow into the pulmonary artery. Deoxygenated blood is delivered to the systemic circulation, resulting in hypoxemia
C. Most common cyanotic congenital heart defect in dogs
D. May result in polycythemia
E. Inherited as a simple autosomal recessive trait
F. Common breeds: Keeshond, English bulldog
G. Clinical signs: May be normal; exercise intolerance, lethargy, syncope, seizures resulting from polycythemia, dyspnea resulting from hypoxemia, ascites
H. Physical examination
1. Cyanosis with and without exercise
2. Systolic left or right basilar murmur of pulmonic stenosis
3. Might not have an audible murmur
4. Normal pulse quality
5. Ascites
6. Jugular venous distension
7. Positive hepatojugular reflex
8. Dyspnea

I. Diagnosis
1. Echocardiogram
a. Right ventricular hypertrophy
b. Interventricular septal flattening
c. Right atrial enlargement
d. Overriding aorta
e. Ventricular septal defect
f. Color flow from right ventricle into aorta
g. Poststenotic dilation of main pulmonary artery
h. Thickened pulmonic valve leaflets
i. Restricted motion of pulmonic valve leaflets
j. Pulmonic regurgitation
k. Elevated peak transpulmonic velocities
2. Electrocardiography
a. Deep S waves in leads I, II, III, aV_f suggestive of right ventricular enlargement
b. Right axis deviation
c. Tall P waves in lead II suggestive of right atrial enlargement
3. Thoracic radiographs
a. Right ventricular enlargement
b. Decreased pulmonary vasculature
c. Poststenotic dilation of main pulmonary artery
4. Packed cell volume (PCV): To monitor polycythemia
5. Arterial blood gas: To monitor hypoxemia

J. Treatment
1. Balloon valvuloplasty: For severe or symptomatic valvular pulmonic stenosis
2. Surgery
a. Resection of the pulmonic stenosis and replacement with a patch graft
b. Patch graft of the ventricular septal defect
c. Blalock Taussig shunt: Connects the left subclavian artery to the pulmonary artery to create a communication between the pulmonary and systemic circulation
d. High degree of difficulty
e. Requires special equipment
f. Costly
g. Not readily available
3. Medical management
a. Phlebotomy. PCV should be maintained below 60% to 65%
b. Hydroxyurea. Side effects related to myelosuppression
c. β-Blockers to relieve hypoxemic episodes associated with sympathetic drive
d. CHF
(1) Oxygen
(2) Diuretics
(3) ACE inhibitor
(4) Pleurocentesis
(5) Abdominocentesis

K. Prognosis
1. Mild: Favorable; rarely develop clinical signs
2. Moderate: May develop clinical signs
3. Severe: Develop clinical signs; shortened life span, risk of sudden death

IX. Atrioventricular valvular dysplasia
A. Mitral and tricuspid valve dysplasia

1. Malformation of the valve leaflets, chordae tendinae or papillary muscles result in regurgitation of the valve, valvular stenosis, or both
2. Occurs in both dogs and cats

B. Common breeds
1. Tricuspid valve dysplasia: Great Dane, German shepherd, golden retriever, Labrador retriever, Weimaraner
2. Mitral valve dysplasia: Great Dane, German shepherd, golden retriever, bull terriers, numerous cat breeds

C. Clinical signs
1. Tricuspid valve dysplasia
 a. May be normal
 b. Exercise intolerance
 c. Lethargy
 d. Syncope
 e. Right-sided heart failure, ascites
 f. Sudden death
2. Mitral valve dysplasia
 a. May be normal
 b. Exercise intolerance
 c. Lethargy
 d. Syncope
 e. Left-sided heart failure
 (1) Cough
 (2) Dyspnea
 f. Sudden death

D. Physical examination
1. Tricuspid valve dysplasia
 a. Systolic right-sided heart murmur
 b. Normal pulse quality
 c. Ascites
 d. Jugular venous distension
 e. Positive hepatojugular reflex
 f. Arrhythmias
2. Mitral valve dysplasia
 a. Systolic left apical murmur
 b. Normal pulse quality
 c. Dyspnea
 d. Arrhythmias

E. Diagnosis
1. Tricuspid valve dysplasia
 a. Echocardiogram
 (1) Right atrial enlargement
 (2) Right ventricular enlargement
 (3) Tricuspid valve displaced toward the right ventricle
 (4) Tricuspid valve apparatus
 (a) Thickened valve leaflets
 (b) Short septal leaflet with restricted motion
 (c) Elongated mural leaflet
 (d) Atrophy, hypertrophy, or malpositioned papillary muscles
 (e) Thickened, short, or elongated chordae tendinae
 (5) Tricuspid regurgitation
 b. Electrocardiography
 (1) Splintered QRS complex
 (2) Deep S waves in leads I, II, III, aV_f suggestive of right ventricular enlargement
 (3) Right axis deviation
 (4) Tall P waves in lead II suggestive of right atrial enlargement
 (5) Supraventricular premature beats
 (6) Atrial fibrillation
 c. Thoracic radiographs
 (1) Normal with mild disease
 (2) Right atrial enlargement
 (3) Right ventricular enlargement
 (4) Caudal vena cava enlargement
 (5) Pleural effusion
2. Mitral valve dysplasia
 a. Echocardiogram
 (1) Left atrial enlargement
 (2) Left ventricular enlargement
 (3) Mitral valve apparatus
 (a) Thickened valve leaflets
 (b) Short or elongated valve leaflets with restricted motion
 (c) Atrophy, hypertrophy, or malpositioned papillary muscles
 (d) Thickened, short, or elongated chordae tendinae
 (4) Mitral regurgitation
 b. Electrocardiography
 (1) Tall R waves in lead II suggestive of left ventricular enlargement
 (2) Wide P waves in lead II suggestive of left atrial enlargement
 (3) Supraventricular premature beats
 (4) Atrial fibrillation
 c. Thoracic radiographs
 (1) Normal with mild disease
 (2) Left atrial enlargement
 (3) Left ventricular enlargement
 (4) Pulmonary venous enlargement
 (5) Pulmonary edema

F. Treatment
1. Balloon valvuloplasty. Tricuspid valve stenosis
2. Surgery
 a. Valvular repair or replacement
 b. High degree of difficulty
 c. Requires special equipment
 d. Costly
 e. Not readily available
3. Medical management
 a. CHF
 (1) Oxygen
 (2) Diuretics
 (3) Positive inotropic support
 (4) Nitroglycerin ointment
 (5) ACE inhibitor
 (6) Pleurocentesis
 (7) Abdominocentesis
 b. Antiarrhythmic therapy

G. Prognosis
1. Mild: Favorable; rarely develop clinical signs
2. Moderate: Favorable; may develop clinical signs
3. Severe: Develop clinical signs, shortened life span, risk of sudden death

X. Ventricular septal defect

A. Perimembranous defects occur most often in dogs

B. Spontaneous closure rarely occurs
C. Typically shunt left to right
D. Common breeds: English springer spaniel, English bulldog
E. Clinical signs: May be normal; exercise intolerance, lethargy, cough, dyspnea
F. Physical examination
 1. Systolic right sternal or left basilar murmur. Loud murmurs are associated with small ventricular septal defects
 2. Diastolic left basilar murmur associated with aortic regurgitation if aortic valve leaflet prolapses into USD
 3. Normal pulse quality
G. Diagnosis
 1. Echocardiogram
 a. Left ventricular enlargement
 b. Left atrial enlargement
 c. Ventricular septal defect
 d. Aortic insufficiency
 2. Electrocardiography
 a. Tall R waves in lead II suggestive of left ventricular enlargement
 b. Wide P waves in lead II suggestive of left atrial enlargement
 3. Thoracic radiographs
 a. Normal in dogs with small septal defects
 b. Left atrial enlargement
 c. Left ventricular enlargement
 d. Pulmonary overcirculation
 e. Pulmonary edema
H. Treatment
 1. Interventional catheterization: Device used to close large ventricular septal defects
 2. Surgery
 a. Pulmonary artery banding
 b. Patch graft
 (1) High degree of difficulty
 (2) Requires special equipment
 (3) Costly
 (4) Not readily available
 3. Medical management. Congestive left-sided heart failure
 a. Oxygen
 b. Diuretics
 c. Positive inotropic support
 d. Nitroglycerin ointment
 e. ACE inhibitor
I. Prognosis
 1. Small defects: Favorable; rarely develop clinical signs
 2. Moderate to large defects: Develop clinical signs; shortened life span without defect closure

XI. Vascular ring anomaly. Persistent right fourth aortic arch
 A. The esophagus is surrounded by the pulmonary artery, ligamentum arteriosum, right aortic arch, heart base, and trachea
 B. Common breeds: German shepherd, Irish setter, Great Dane
 C. Clinical signs of regurgitation are attributed to esophageal obstruction
 D. Diagnosed with thoracic radiographs, angiography, or esophageal endoscopy
 E. Treatment requires surgical ligation of the ligamentum arteriosum
 F. Prognosis is good to guarded. Residual esophageal functional and structural damage may persist

ACQUIRED HEART DISEASE

I. Myocardial disease
 A. Dogs
 1. Dilated cardiomyopathy
 2. Arrhythmogenic right ventricular cardiomyopathy
 3. Hypertrophic cardiomyopathy
 B. Cats
 1. Hypertrophic cardiomyopathy
 2. Dilated cardiomyopathy
 3. Restrictive cardiomyopathy
 4. Arrhythmogenic right ventricular cardiomyopathy
 C. Dilated cardiomyopathy in dogs
 1. Heritable in some breeds (boxer, Doberman pinscher, Great Dane, Newfoundland)
 2. More common in male dogs
 3. Preclinical: Denoted by the presence of left ventricular dilation, left ventricular systolic dysfunction, and ventricular arrhythmias in the absence of clinical signs
 4. Clinical: Left ventricular dilation, left ventricular systolic dysfunction, and ventricular arrhythmias in the presence of clinical signs
 5. Common breeds: Doberman pinscher, Newfoundland, Irish wolfhound, Great Dane, Labrador retriever, cocker spaniel, boxer, Saint Bernard, Old English sheepdog, Dalmatian
 6. Causes
 a. Tachycardia induced
 (1) Myocardial dysfunction resulting from a persistently fast heart rate (>200 beats/min)
 (2) Enlargement of all four heart chambers
 (3) May resolve with appropriate heart rate control
 b. Toxic. Adriamycin (doxorubicin)
 (1) Patients present with arrhythmias and myocardial failure
 (2) Dose dependent and reversible
 (3) Cardiotoxicity occurs at cumulative doses of 250 mg/m^2
 c. Infectious myocarditis
 (1) *Toxoplasma gondii*
 (2) *Trypanosoma cruzi*
 (a) Vector is the reduvid bug
 (b) Forms
 i. Trypomastigote in blood
 ii. Amastigote in host tissue
 (c) Presentation
 i. Ventricular arrhythmias and atrioventricular block
 ii. Systolic dysfunction of primarily the right ventricle
 iii. Heart failure

(d) No reliable cure
(e) Treat symptomatically
(3) Parvovirus
(a) Affected puppies during the 1970s and 1980s
(b) Not routinely encountered now that most dogs are appropriately vaccinated
(4) Distemper virus: Uncommon given that most dogs are appropriately vaccinated
d. Endocrine
(1) Hypothyroidism
(a) May contribute
e. Nutritional
(1) Taurine deficiency
(a) Cocker spaniels
(b) Golden retrievers
(2) Carnitine deficiency
(a) Cocker spaniels
(b) Boxers
f. Idiopathic. No identifiable cause

7. Clinical signs
a. May be normal
b. Exercise intolerance
c. Lethargy
d. Left- and right-sided heart failure
(1) Cough
(2) Dyspnea
(3) Ascites
(4) Syncope
(5) Sudden death
(6) Anorexia
(7) Weight loss

8. Physical examination
a. Systolic left or right heart murmur associated with atrioventricular valvular regurgitation
b. Gallop
c. Arrhythmia
d. Normal to decreased pulse quality
e. Pulse deficits
f. Normal to pale mucous membrane color
g. Dyspnea
h. Ascites
i. Hepatosplenomegaly
j. Jugular venous distension
k. Positive hepatojugular reflex

9. Diagnosis
a. Echocardiogram
(1) Left or right ventricular dilation
(2) Decreased systolic function
(3) Normal to decreased left ventricular wall thickness
(4) Left or right atrial enlargement
(5) Mitral or tricuspid regurgitation
(6) Normal to decreased transaortic velocities
b. Electrocardiography (Figure 12-3)
(1) Tall R waves in lead II suggestive of left ventricular enlargement
(2) Wide P waves in lead II suggestive of left atrial enlargement
(3) Ventricular arrhythmias
(4) Supraventricular premature beats
(5) Atrial fibrillation
c. Thoracic radiographs
(1) Normal in dogs with an early stage of the disease
(2) Left atrial enlargement
(3) Left ventricular enlargement
(4) Right atrial enlargement
(5) Right ventricular enlargement
(6) Enlarged pulmonary veins
(7) Pulmonary edema
(8) Pleural effusion
d. Plasma taurine levels
e. Thyroid panel (thyroxine [T_4], free T_4 by equilibrium dialysis [ED], thyroid-stimulating hormone [TSH])
f. Chagas titer

10. Treatment: Medical management
a. Preclinical
(1) ACE inhibitor
(2) The use of β-blockers is under investigation
b. CHF
(1) Oxygen
(2) Diuretics
(3) Positive inotropic support

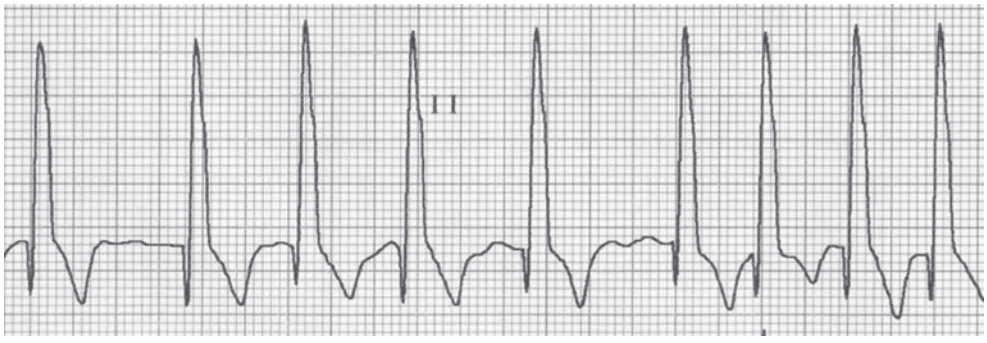


Figure 12-3 Lead II electrocardiogram tracing from a dog indicating atrial fibrillation and left ventricular enlargement. Note the irregular rhythm, lack of P waves, and widened QRS complex. 50 mm/sec; 10 mm/mV. (From Tilley LP et al. *Manual of Canine and Feline Cardiology*, 4th ed. Philadelphia, 2007, Saunders.)

(4) Nitroglycerin ointment
(5) ACE inhibitor
(6) Pleurocentesis
(7) Abdominocentesis
c. Antiarrhythmic therapy
d. Nutritional supplements: Taurine, L-carnitine, fish oil, coenzyme Q10

11. Prognosis
a. Tachycardia induced: Favorable with adequate heart rate control
b. Toxic: Favorable
c. Infectious myocarditis: Poor
d. Endocrine: Hypothyroidism. Favorable with thyroid supplementation
e. Nutritional
(1) Taurine deficiency. Favorable with taurine supplementation
(2) L-carnitine deficiency. Favorable with carnitine supplementation
f. Idiopathic. Poor

12. Breed-related variations
a. Boxer: Present primarily with arrhythmias
b. Cocker spaniels: Associated with taurine and L-carnitine deficiency
c. Golden retriever
(1) Canine X-linked muscular dystrophy
(2) Myocardial lesions develop before 1 year of age
(3) Prognosis is guarded to poor
d. Great Dane: X-linked inheritance pattern
e. Irish wolfhound
(1) Frequently present with atrial fibrillation
(2) Often have biventricular heart failure
f. Portuguese water dogs: juvenile onset, poor prognosis

D. Arrhythmogenic right ventricular cardiomyopathy in dogs
1. Characterized pathologically by fatty or fibrofatty infiltration of the right ventricle
2. Familial in boxers
3. Inherited as an autosomal dominant trait
4. Characterized by syncope, ventricular arrhythmias with a right ventricular origin, and occasionally systolic dysfunction (Figure 12-4)
5. Therapy consists of antiarrhythmic medication such as sotalol or mexilitine combined with atenolol
6. High risk of sudden death

E. Hypertrophic cardiomyopathy in dogs
1. Characterized by idiopathic concentric hypertrophy of the ventricle
2. Rarely occurs in dogs
3. Rule out secondary causes of ventricular hypertrophy
a. Aortic stenosis
b. Systemic hypertension
c. Significant dehydration
d. Infiltrative neoplasia

F. Hypertrophic cardiomyopathy in cats
1. Characterized by concentric hypertrophy of the ventricle
2. Hypertrophic obstructive cardiomyopathy (HOCM) occurs when there is a dynamic obstruction to blood entering the left ventricular outflow tract secondary to systolic anterior motion of the mitral valve
3. Inheritance patterns: Autosomal dominant in Maine coon cats
4. Common breeds: Maine coon, Persian ragdoll, American shorthair, domestic shorthair, domestic longhair
5. Secondary causes of ventricular hypertrophy
a. Aortic stenosis
b. Systemic hypertension
c. Hyperthyroidism
d. Significant dehydration
e. Infiltrative neoplasia
f. Acromegaly
6. Clinical signs: May be normal; exercise intolerance, lethargy, left-sided and right-sided heart failure (cough, dyspnea, ascites), syncope, sudden death, weight loss, decreased appetite, sudden lameness
7. Factors that may result in clinical decompensation: Anesthesia, long-acting corticosteroids, stress
8. Physical examination
a. Systolic sternal murmur
b. Gallop
c. Arrhythmia
d. Normal pulse quality

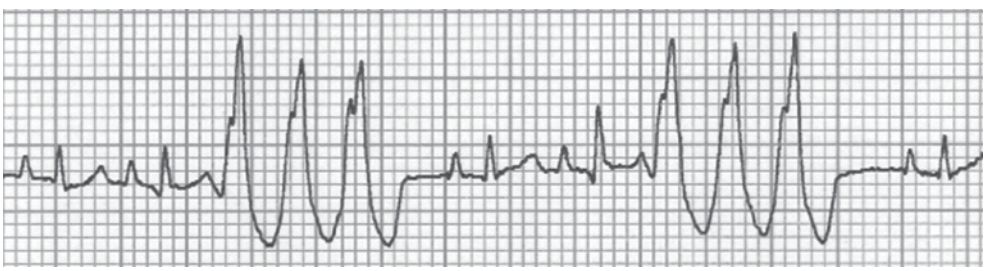


Figure 12-4 Lead II electrocardiogram tracing from a 7-year-old male, castrated boxer with arrhythmogenic right ventricular cardiomyopathy. Ventricular premature beats with left bundle-branch block morphology are a common finding in dogs with this condition. 25 mm/sec; 0.5 cm/mV. (From Tilley LP. *Manual of Canine and Feline Cardiology*, 4th ed. Philadelphia, 2007, Saunders.)

e. Normal to pale mucous membrane color
f. Dyspnea
g. Crackles
h. Ascites
i. Hepatosplenomegaly
j. Jugular venous distension
k. Pale nail beds
l. Hypothermia

9. Diagnosis
 a. Echocardiogram
 (1) Global or focal left ventricular wall thickening (>6 mm)
 (2) Papillary muscle hypertrophy
 (3) Left and right atrial enlargement
 (4) Mitral regurgitation
 (5) Systolic anterior motion of the mitral valve
 (6) Normal to increased left ventricular outflow tract velocities
 (7) Diastolic dysfunction
 (8) Pleural effusion
 (9) Pericardial effusion
 b. Electrocardiography
 (1) Tall R waves in lead II suggestive of left ventricular enlargement
 (2) Wide P waves in lead II suggestive of left atrial enlargement
 (3) Ventricular arrhythmias
 (4) Supraventricular arrhythmias
 c. Thoracic radiographs (Figure 12-5)
 (1) Normal in cats with an early stage of the disease
 (2) Generalized cardiomegaly
 (3) Left and/or right atrial enlargement
 (4) Left ventricular enlargement
 (5) Enlarged pulmonary veins
 (6) Pulmonary edema
 (7) Pleural effusion
 d. Thyroid
 e. Blood pressure
10. Treatment. Medical management
 a. β-Blocker or calcium channel blocker
 b. ACE inhibitor
 c. CHF
 (1) Oxygen
 (2) Diuretics
 (3) ACE inhibitor
 (4) Pleurocentesis
 (5) Abdominocentesis
 d. Antiarrhythmic therapy
 e. Thromboembolism
 (1) Aspirin, clopidogrel
 (2) Pain medication
 (3) Physical therapy
11. Prognosis
 a. Highly variable depending on ventricular wall thickness, atrial enlargement, and presence of clinical signs
 b. Mild: Favorable, rarely develop clinical signs
 c. Moderate: May develop clinical signs
 d. Severe: Develop clinical signs, prognosis is poor

G. Dilated cardiomyopathy in cats
 1. Characterized by increased ventricular size and a reduction in contractility
 2. Causes: Nutritional, taurine deficiency, idiopathic
 3. Clinical signs: Cough, dyspnea, vomiting, anorexia, lethargy, syncope, sudden lameness, sudden death
 4. Physical examination
 a. Systolic sternal murmur
 b. Gallop
 c. Arrhythmia
 d. Normal to decreased pulse quality
 e. Normal to pale mucous membrane color
 f. Dyspnea
 g. Crackles
 h. Ascites
 i. Hepatosplenomegaly
 j. Jugular venous distension
 k. Pale nail beds
 l. Hypothermia
 5. Diagnosis
 a. Echocardiogram
 (1) Left ventricular dilation
 (2) Decreased fractional shortening
 (3) Left and/or right atrial enlargement
 (4) Mitral regurgitation
 (5) Pleural effusion
 (6) Pericardial effusion
 b. Thoracic radiographs
 (1) Cardiomegaly
 (2) Pleural effusion
 (3) Enlarged pulmonary veins
 (4) Pulmonary edema
 c. Plasma or whole blood taurine concentration
 6. Treatment. Medical management
 a. Positive inotropic therapy
 b. Taurine supplementation
 c. ACE inhibitor
 d. CHF
 (1) Oxygen
 (2) Diuretics
 (3) Pleurocentesis
 (4) Abdominocentesis
 e. Antiarrhythmic therapy
 f. Thromboembolism
 (1) Aspirin, clopidogrel
 (2) Pain medication
 (3) Physical therapy
 7. Prognosis: Favorable with taurine supplementation, poor if idiopathic

H. Restrictive cardiomyopathy in cats
 1. Classified as normal to mildly increased ventricular wall thickness with atrial enlargement and evidence of diastolic dysfunction
 2. May be a result of myocarditis
 3. Clinical signs: Similar to hypertrophic cardiomyopathy
 4. Physical examination: Similar to hypertrophic cardiomyopathy
 5. Diagnosis
 a. Echocardiogram

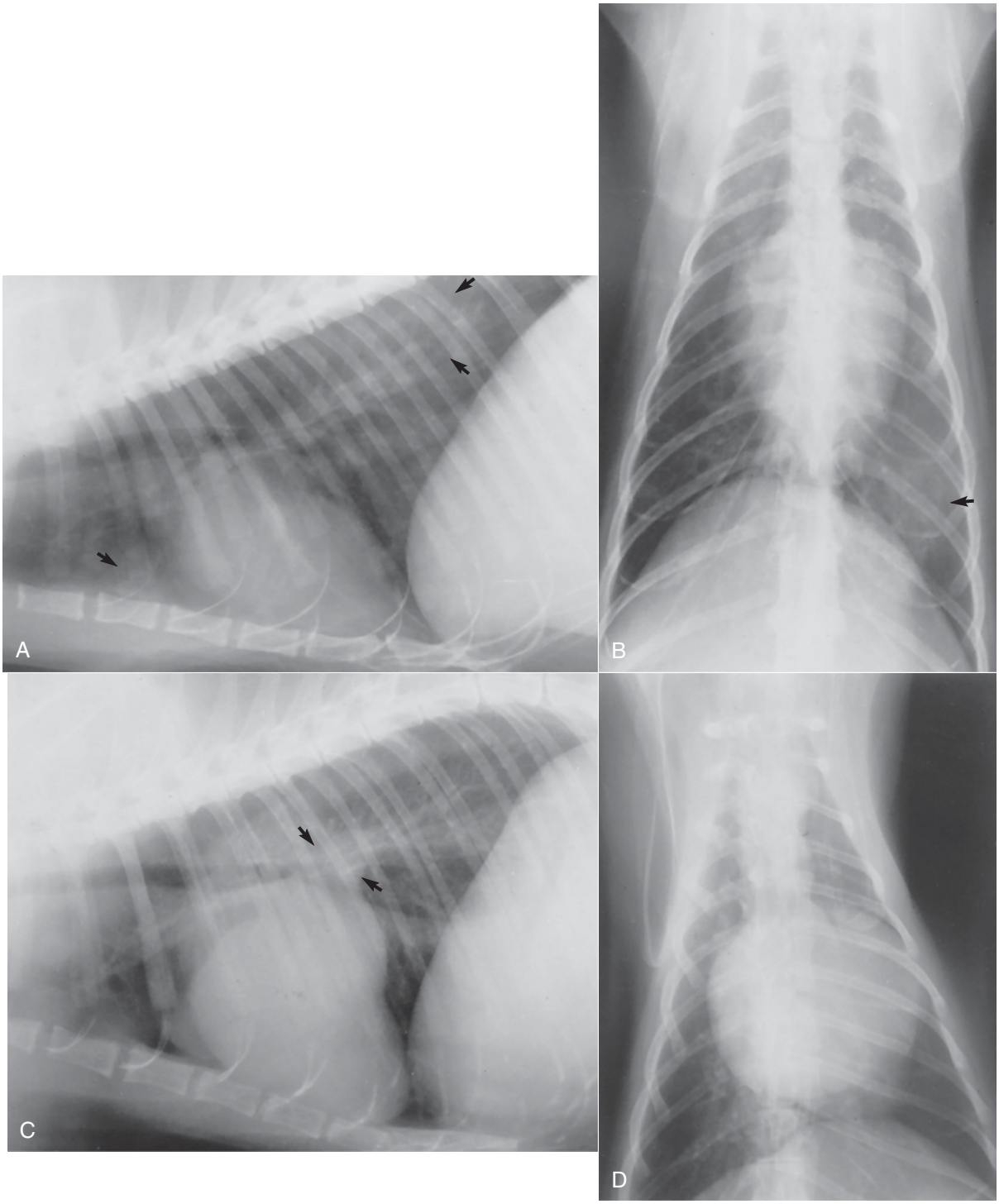


Figure 12-5 Radiographic examples of feline hypertrophic cardiomyopathy. Lateral **(A)** and dorsoventral **(B)** views showing atrial and mild ventricular enlargement along with patchy interstitial pulmonary edema (*arrowheads*) in a male domestic shorthair cat with left-sided congestive heart failure. Lateral **(C)** and dorsoventral **(D)** views of a male Siamese cat with marked atrial enlargement, dilated pulmonary veins (*arrowheads,* C), and atrial fibrillation. (From Nelson RW, Couto CG. *Small Animal Internal Medicine*, 4th ed. St Louis, 2009, Mosby.)

(1) Normal to mild left ventricular wall thickening
(2) Diastolic ventricular dysfunction
(3) Biatrial enlargement
(4) Mitral regurgitation
(5) Pleural effusion
(6) Pericardial effusion
b. Electrocardiography: Similar to hypertrophic cardiomyopathy
c. Thoracic radiographs: Similar to hypertrophic cardiomyopathy
6. Treatment. Medical management
a. β-Blocker or calcium channel blocker
b. ACE inhibitor
c. CHF
(1) Oxygen
(2) Diuretics
(3) Pleurocentesis
(4) Abdominocentesis
d. Antiarrhythmic therapy
e. Thromboembolism
(1) Aspirin, clopidogrel
(2) Pain medication
(3) Physical therapy
7. Prognosis
a. Mild: Favorable; rarely develop clinical signs
b. Moderate: May develop clinical signs
c. Severe: Develop clinical signs; prognosis is poor

I. Arrhythmogenic right ventricular cardiomyopathy in cats
1. Characterized by fatty or fibrofatty infiltration of the right ventricle
2. Clinical signs
a. May be normal
b. Exercise intolerance
c. Lethargy
d. Right-sided heart failure: Cough, dyspnea, ascites
e. Syncope
f. Sudden death
g. Weight loss
h. Decreased appetite
3. Physical examination
a. Systolic sternal murmur
b. Gallop
c. Arrhythmia
d. Normal pulse quality
e. Normal to pale mucous membrane color
f. Dyspnea
g. Crackles
h. Ascites
i. Hepatosplenomegaly
j. Jugular venous distension
k. Hypothermia
4. Diagnosis
a. Echocardiogram
(1) Right ventricular enlargement
(2) Right atrial enlargement
(3) Tricuspid regurgitation
(4) Pleural effusion
(5) Pericardial effusion
b. Electrocardiography. Ventricular arrhythmias
c. Thoracic radiographs
(1) Normal in cats with an early stage of the disease
(2) Generalized cardiomegaly
(3) Pleural effusion
5. Treatment. Medical management
a. Positive inotropic support
b. ACE inhibitor
c. CHF
(1) Oxygen
(2) Diuretics
(3) Pleurocentesis
(4) Abdominocentesis
d. Antiarrhythmic therapy
6. Prognosis poor

II. Valvular endocardiosis
A. Commonly acquired heart disease in middle-aged to older dogs
B. Occurs with less frequency in cats
C. Result of myxomatous degeneration of the atrioventricular valves (mitral valve more frequently than tricuspid valve)
D. Progression to heart failure is highly variable
E. Acute decompensation occurs with chordae tendinae rupture, left atrial rupture, and the onset of arrhythmias
F. More common in small breed dogs but does occur in large and giant breeds
G. Common breeds: Cavalier King Charles spaniel, dachshund, miniature poodle, cocker spaniel, Pomeranian, Miniature schnauzer, Boston terrier, Chihuahua
H. Clinical signs: May be normal; exercise intolerance, lethargy, anorexia, weight loss, left or right heart failure (cough, dyspnea, ascites), syncope, sudden death
I. Physical examination
1. Systolic left apical murmur with mitral regurgitation
2. Systolic right heart murmur with tricuspid regurgitation
3. Mid-systolic click
4. Normal pulse quality
5. Arrhythmia
6. Gallop
7. Dyspnea
8. Signs of right-sided heart failure if tricuspid endocardiosis or pulmonary hypertension
a. Ascites
b. Positive hepatojugular reflex
c. Jugular venous distension
J. Diagnosis
1. Echocardiogram
a. Left atrial enlargement
b. Left ventricular enlargement
c. Normal, increased, or decreased systolic function
d. Normal left ventricular wall thickness
e. Thickened valve leaflets
f. Prolapse or flail of the valve leaflets
g. Mitral regurgitation

h. Normal transaortic and transpulmonic velocities
i. Signs of right heart enlargement with tricuspid endocardiosis or pulmonary hypertension
(1) Right atrial enlargement
(2) Right ventricular enlargement
(3) Tricuspid regurgitation
(4) Pulmonic regurgitation
(5) Pulmonary artery enlargement

2. Electrocardiography
a. Sinus arrhythmia
b. Sinus tachycardia
c. Tall R waves in lead II suggestive of left ventricular enlargement
d. Wide P waves in lead II suggestive of left atrial enlargement
e. Tall P waves in lead II suggestive of right atrial enlargement
f. Supraventricular or ventricular premature beats
g. Atrial fibrillation or flutter

3. Thoracic radiographs
a. Normal in dogs with an early stage of the disease
b. Left ventricular enlargement
c. Left atrial enlargement
d. Mainstem bronchial compression
e. Enlarged pulmonary veins
f. Pulmonary edema
g. Signs of right-sided heart disease with tricuspid endocardiosis or pulmonary hypertension
(1) Right atrial enlargement
(2) Right ventricular enlargement
(3) Pulmonary artery enlargement
(4) Pleural effusion

4. Blood pressure
a. Normal systolic pressure
b. May be decreased in severe cases with reduced cardiac output
c. May be increased with comorbidities such as renal or endocrine disease

5. Serum biochemistry panel and electrolytes

K. Treatment. Medical management
1. Preclinical
a. No medication shown to delay the progression of the disease
b. ACE inhibitors frequently prescribed
c. The use of β-blockers is under investigation

2. CHF
a. Oxygen
b. Diuretics
c. Positive inotropic support
d. Nitroglycerin ointment
e. ACE inhibitor
f. Pleurocentesis
g. Abdominocentesis

3. Mainstem bronchial compression
a. Cough suppressant such as hydrocodone, butorphanol, or dextromethorphan
b. Bronchodilator such as theophylline

4. Systemic hypertension: Afterload reducers such as hydralazine, amlodipine, or ACE inhibitors

5. Antiarrhythmic therapy

6. Surgery: Valvular repair or replacement; high degree of difficulty, requires special equipment, costly, not readily available

L. Prognosis: Dependent on progression and severity of the disease. Cavalier King Charles spaniels may have a faster rate of progression

III. Valvular endocarditis
A. Incidence is higher in large breed dogs and dogs with congenital heart disease (aortic stenosis and ventricular septal defects)
B. Most common valves affected are aortic, mitral
C. Most common infectious organisms
1. *Escherichia coli*
2. *Staphylococcus aureus*
3. *Streptococcus* spp.
4. *Corynebacterium*
5. *Bartonella vinsonii* more common in culture-negative endocarditis

D. Embolism of the kidney, spleen, liver, gastrointestinal (GI) tract, brain and limbs have been reported
E. Clinical signs: May be normal; exercise intolerance, lethargy, left-sided heart failure (cough, dyspnea), syncope, sudden death, anorexia, weight loss
F. Physical examination
1. Systolic left apical murmur if mitral regurgitation
2. Diastolic left basilar murmur if aortic regurgitation
3. Systolic left basilar murmur if aortic stenosis
4. Systolic right sternal murmur if ventricular septal defect
5. Gallop
6. Arrhythmia
7. Normal to increased pulse quality
8. Pulse deficits
9. Normal to pale mucous membrane color
10. Dyspnea
11. Painful joints resulting from septic arthritis
12. Fever

G. Diagnosis
1. Echocardiogram
a. Left ventricular dilation
b. Left atrial enlargement
c. Normal to increased left ventricular wall thickness. Increased with aortic stenosis
d. Mitral regurgitation
e. Aortic regurgitation
f. Normal to increased transaortic velocities
g. Vegetative valvular lesions
h. Thickened aortic valve leaflets

2. Electrocardiography
a. Tall R waves in lead II suggestive of left ventricular enlargement
b. Wide P waves in lead II suggestive of left atrial enlargement
c. Ventricular arrhythmias
d. Supraventricular premature beats
e. Atrial fibrillation

3. Thoracic radiographs
a. Normal in dogs with an early stage of the disease
b. Left atrial enlargement

c. Left ventricular enlargement
d. Enlarged pulmonary veins
e. Pulmonary edema
4. Complete blood cell count (CBC)
a. Anemia
b. Leukocytosis with a left shift
c. Monocytosis
5. Biochemistry panel
a. Azotemia
b. Hypoalbuminemia
c. Hyperglobulinemia
6. Blood culture. False-negative if there is prior antibiotic therapy or intermittent bacterial shedding
7. Urine culture
8. Blood pressure
a. Normal to decreased systolic pressure
b. Decreased diastolic pressure

H. Treatment. Medical management
1. Antibiotic therapy
a. Based on culture and sensitivity
b. Broad spectrum
2. CHF
a. Oxygen
b. Diuretics
c. Positive inotropic support
d. Nitroglycerin ointment
e. ACE inhibitor
3. Antiarrhythmic therapy

I. Prognosis: Guarded to poor

IV. Heartworm disease

A. Caused by *Dirofilaria immitis*

B. Transmitted by mosquitoes

C. Life cycle (Figure 12-6)
1. L1 microfilaria are ingested by a mosquito (Table 12-2)
2. Within the mosquito, the L1 becomes L2 and the L2 becomes L3. Maturation time in the mosquito is dependent on ambient temperature
3. L3 larvae are transmitted by the mosquito to a host
4. L3 becomes L4 within the host tissue
5. L4 molts to L5 adults
6. The L5 enters the vasculature and migrates to the heart and pulmonary arteries

D. Occult heartworm disease means the patient has adult heartworms without circulating microfilariae

E. Heartworms can result in end-organ damage
1. Kidneys: Deposition of antigen-antibody complexes results in glomerulonephritis
2. Lungs
a. Pulmonary damage from inflammation and thromboembolic events
b. Eosinophilic granulomas
3. Aberrant worm migration to brain, kidneys, and eyes

F. Canine
1. Prepatent period is 5 to 7 months
2. The life span of the adult heartworm is approximately 5 years
3. Microfilaria can be passed from a mother to her offspring
4. Clinical signs: May be normal; cough, dyspnea, exercise intolerance, lethargy, ascites, syncope, anorexia, weight loss, hemoptysis, sudden death

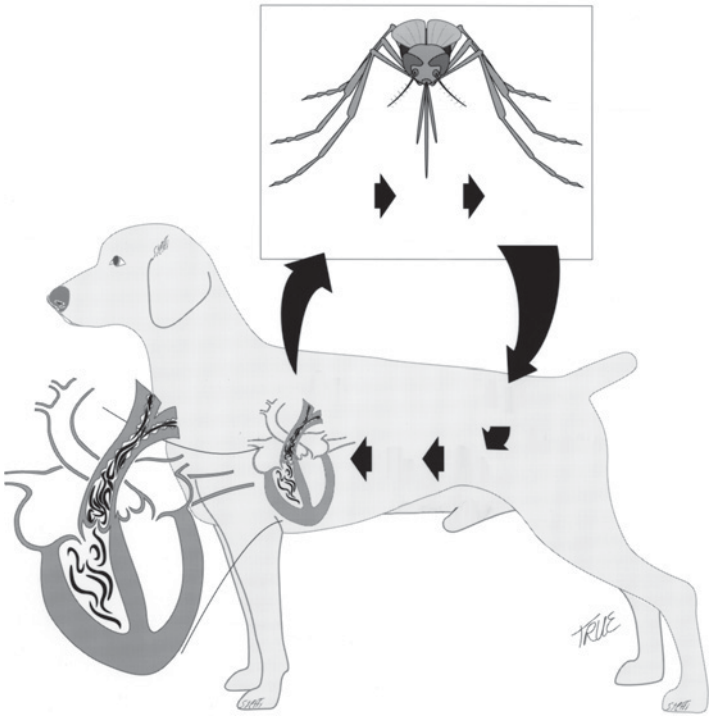


Figure 12-6 Life cycle of dirofilaria immitis in the dog. (From Atkins CE. Heartworm disease. From Allen DG, ed. *Small Animal Medicine*. Philadelphia, 1991, JB Lippincott; pp 341-363.)

Table 12-2 Criteria to Differentiate *Dirofilaria Immitis* Microfilaria from Acanthocheilonema Reconditum *(Dipetalonema Reconditam)* Using a Modified Knott's Test

Microfilaria Criteria	*Dirofilaria Immitis*	(Acanthocheilonema Reconditum) *Dipetalonema Reconditum*
Head	Tapered	Blunt
Body	Straight	Curved
Motion	Stationary	Progressive
Relative length	Longer	Shorter

5. Physical examination
 a. May be normal
 b. Cough
 c. Abnormal bronchovesicular sounds
 d. Systolic right heart murmur of tricuspid regurgitation. Caused by elevated right ventricular pressures secondary to pulmonary hypertension, the physical presence of the heartworms across the tricuspid valve, or tricuspid valve endocardiosis
 e. Arrhythmias
 f. Split-second heart sound
 g. Fever
 h. Right-sided heart failure
 (1) Ascites
 (2) Positive hepatojugular reflex
 (3) Jugular venous distension
6. Caval syndrome occurs when the heartworms migrate into the right atrium, right ventricle and vena cava
 a. Patients may have port wine-colored urine with hemoglobinuria
 b. Patients often develop renal and hepatic failure, congestive right heart failure, and disseminated intravascular coagulation
7. Diagnosis
 a. Heartworm antigen test: Detects antigen found in the uterus of female worms. Enzyme-linked immunosorbent assay (ELISA) tests are highly sensitive and specific
 b. Heartworm antibody test. Nonspecific and no longer used in dogs
 c. Microfilaria test such as Difil or modified Knott
 (1) Microfilaria are present in 70% to 80% of dogs
 (2) Potential reasons for an absence of microfilaria
 (a) Testing within the prepatent period
 (b) Low worm burden
 (c) All-male infection
 (d) Immunologic destruction by the host
 (e) Receiving macrolide preventative
 d. Thoracic radiographs
 (1) May be normal
 (2) Enlarged main pulmonary artery (Figure 12-7)
 (3) Enlarged and tortuous caudal pulmonary arteries
 (4) Blunting of the caudal pulmonary arteries
 (5) Right ventricular enlargement
 (6) Bronchointerstitial to alveolar pulmonary pattern
 e. Electrocardiography
 (1) Deep S waves in leads I, II, III, aV_f suggestive of right ventricular enlargement
 (2) Right axis deviation
 (3) Tall P waves in lead II suggestive of right atrial enlargement
 f. Echocardiogram
 (1) May be normal
 (2) Right ventricular enlargement
 (3) Main pulmonary artery enlargement
 (4) Tricuspid regurgitation
 (5) Pulmonic regurgitation
 (6) Heartworms within the right atrium, ventricle, or pulmonary artery
 g. CBC
 (1) May be normal
 (2) Anemia
 (3) Neutrophilia
 (4) Lymphopenia
 (5) Eosinophilia
 (6) Basophilia
 (7) Circulating microfilaria
 (8) Thrombocytopenia
 h. Biochemistry panel
 (1) May be normal
 (2) Elevated serum alanine transferase, serum alkaline phosphatase
 (3) Hyperglobulinemia
 (4) Azotemia
 i. Urinalysis: Proteinuria
8. Treatment
 a. Microfilariacidal
 (1) Slow kill rate with preventative doses of ivermectin, milbemycin oxime, and selamectin
 (2) Corticosteroids, antihistamines, or both may be administered 1 hour before microfilaricide to decrease the chance for adverse effects

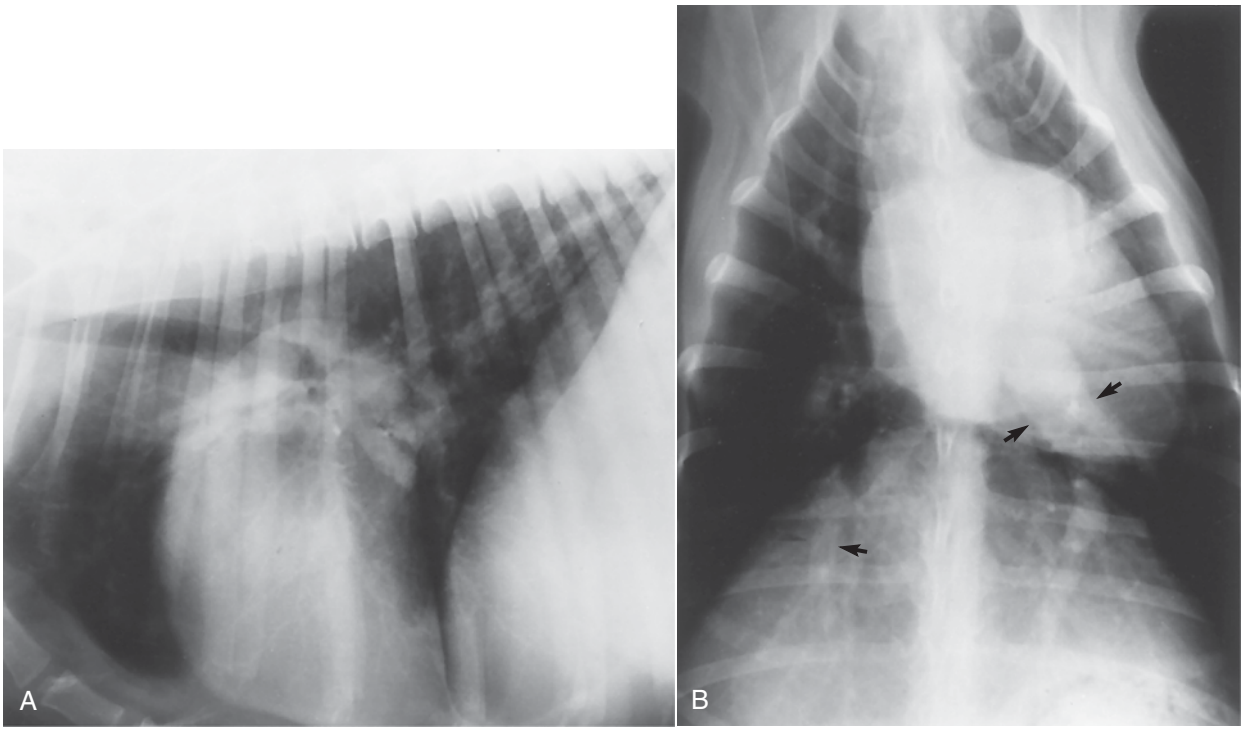


Figure 12-7 **A,** Lateral; **B,** dorsoventral (DV) radiographs from a German shepherd with advanced heartworm disease. Enlargement of pulmonary arteries is seen, especially on DV view (*arrowheads,* B). (From Nelson RW, Couto CG. *Small Animal Internal Medicine*, 4th ed. St Louis, 2009, Mosby.)

b. Adulticidal
 (1) Melarsomine (Immiticide)
 (a) Arsenic based compound
 (b) Safer than its predecessor, thiacetarsemide
 (c) Standard protocol
 i. Consists of two intramuscular (IM) injections 24 hours apart
 ii. Seroconversion to a negative antigen test reaches approximately 75%
 iii. May be selected in cases with financial issues, or for dogs without clinical signs and with essentially normal diagnostic tests (thoracic radiographs and blood work)
 (d) Split protocol—Preferred
 i. Consists of a single IM injection followed in 4 to 6 weeks by two IM injections 24 hours apart
 ii. Seroconversion to a negative antigen test reaches approximately 90%
 iii. Recommended for dogs with clinical signs and abnormal diagnostic tests
 iv. Associated with fewer adverse effects
 v. Requires added expense and a longer period of cage confinement
 (e) Adverse effects typically occur 5 to 7 days after melarsomine injection and include cough, anorexia, and fever
 (f) At home care
 i. Strict cage confinement for 4 weeks with the standard protocol and 8 weeks with the split protocol
 ii. Concurrent administration of antiinflammatory corticosteroids
 iii. Aspirin therapy is not recommended
 iv. Concurrent corticosteroid and nonsteroidal anti-inflammatory medication is contraindicated
 (g) Recheck heartworm antigen test 4 to 6 months following treatment
 (2) Ivermectin
 (a) Kills adult heartworms after approximately 31 months of consecutive monthly administration
 (b) Not recommended routinely as adulticide therapy because of ongoing pulmonary and myocardial damage and potential development of caval syndrome
 (c) May be selected in dogs with concurrent renal or hepatic disease
 (3) Surgery
 (a) The physical removal of heartworms is recommended with caval syndrome when the heartworms are

present within the right atrium or right ventricle resulting in a hemolytic crisis or an obstruction to blood flow
(b) Dogs require melarsomine treatment following surgical removal of the heartworms

9. Prevention
 a. Begin prevention by 6 to 8 weeks of age, especially in heartworm endemic locations
 b. Macrolide lactones
 (1) Derived from *Streptomyces* spp.
 (2) Administered monthly
 (3) Microfilaricidal
 (a) Ivermectin kills microfilaria gradually
 (b) Milbemycin kills microfilaria quickly, creating a potential risk of adverse reactions
 (4) Ivermectin (Heartgard Plus) has adulticide effects after prolonged continuous monthly use
 (5) Safe when used in collies at the preventative dose
 (6) Oral examples
 (a) Ivermectin (Heartgard)
 (b) Milbemycine oxime (Interceptor).
 (7) Topical examples: Selamectin (Revolution), moxidectin (Advantage Multi)
 c. Diethylcarbamazine
 (1) Administered daily
 (2) Efficacious against L3 and early L4 larvae
 (3) Administration to microfilaremic dogs can result in an anaphylactic reaction and death
10. Prognosis
 a. Favorable in mild to moderate cases
 b. Guarded if severe disease with clinical signs
 c. Guarded to poor with caval syndrome

G. Feline
1. Increased risk in male cats
2. The prepatent period is 8 months
3. The life span of an adult heartworm is less than 4 years
4. The heartworm burden is typically lower, in the range of one to nine worms
5. Clinical signs: May be normal; lethargy, vomiting, cough, dyspnea, anorexia, syncope, sudden death
6. Physical examination
 a. May be normal
 b. Murmur
 c. Arrhythmia
 d. Gallop rhythm
 e. Abnormal bronchovesicular sounds
 f. Dyspnea
 g. Ascites
 h. Jugular venous distension
7. Diagnosis
 a. Heartworm antibody test: Indicates prior or current heartworm infection
 b. Heartworm antigen test
 (1) Detects antigen found in the uterus of gravid female heartworms
 (2) Not particularly sensitive for detecting heartworms in cats. Positive in less than 50% of heartworm-positive cats
 c. Microfilaria test such as Difil or modified Knott. Circulating microfilaria are present in only approximately 20% of cats
 d. Thoracic radiographs
 (1) May be normal
 (2) Pulmonary artery enlargement
 (3) Bronchointerstitial to alveolar pulmonary pattern
 (4) Generalized heart enlargement
 (5) Pleural effusion
 e. Echocardiogram
 (1) May be normal
 (2) Right ventricular enlargement
 (3) Main pulmonary artery enlargement
 (4) Tricuspid regurgitation
 (5) Heartworms within the right atrium, ventricle, or pulmonary artery
 (6) Considered a sensitive test for detecting the presence of heartworms in cats
 f. CBC
 (1) May be normal
 (2) Anemia
 (3) Neutrophilia
 (4) Lymphopenia
 (5) Eosinophilia
 (6) Basophilia
 (7) Circulating microfilaria
 (8) Thrombocytopenia
 g. Biochemistry panel
 (1) May be normal
 (2) Hyperglobulinemia
 (3) Azotemia
 h. Urinalysis: Proteinuria
8. Treatment
 a. Microfilariacide
 (1) Microfilaria-positive cats are rarely encountered
 (2) Preventative dose of ivermectin or milbemycine oxime
 b. Adulticide
 (1) Melarsomine: Not recommended because of an association with important and life-threatening adverse effects
 (2) Medical management: Treat clinical signs with corticosteroids, bronchodilators, and oxygen as needed
 (3) Caval syndrome: Surgical removal
9. Prognosis: Favorable to guarded
10. Monthly prevention
 a. Oral examples
 (1) Ivermectin (Heartgard)
 (2) Milbemycine oxime (Interceptor)
 b. Topical examples
 (1) Selamectin (Revolution)
 (2) Moxidectin (Advantage Multi)

V. Pericardial disease
 A. More common in dogs
 B. Congenital disorders
 1. Cysts: Rare in dogs. Presenting signs are similar to pericardial effusion
 2. Peritoneopericardial diaphragmatic hernia
 a. Occurs because of abnormal fusion of the septum transversum and pleuroperitoneal folds
 b. Liver is the most common herniated abdominal organ
 c. Common breeds
 (1) Dogs: Weimaraner
 (2) Cats
 (a) Persian
 (b) Himalayan
 d. Clinical signs frequently related to respiratory difficulty or GI upset
 e. Diagnosis
 (1) Thoracic radiographs
 (a) Cardiomegaly
 (b) Silhouette between the heart and diaphragm
 (c) Abdominal contents within the thorax
 (2) ECG
 (a) Sinus tachycardia
 (b) Small QRS complexes
 (3) Echocardiogram: Abdominal contents present with the pericardium and displacing the heart
 f. Treatment: Surgical repair in symptomatic patients
 g. Prognosis: Excellent unless adhesions complicate the surgical repair
 C. Acquired disorders
 1. Constrictive pericardial disease
 a. Fibrosis of the pericardium leads to restriction of cardiac filling and a reduction in cardiac output
 b. Idiopathic or inflammatory
 c. Difficult to diagnose
 d. Treatment consists of surgically stripping the pericardium from the myocardium and is associated with increased morbidity and mortality
 2. Pericardial effusion
 a. Results in impaired ventricular filling and decreased cardiac output
 b. Occurs more often in middle-aged to older, large-breed dogs
 c. Causes
 (1) Neoplasia
 (a) Hemangiosarcoma
 i. Originates from the right auricle
 ii. Commonly reported breeds: Golden retriever, German shepherd
 iii. High metastatic rate
 (b) Heart-base tumors (chemodectoma, aortic body tumor)
 i. Commonly reported breeds: Brachycephalic (Boston terrier, boxer)
 ii. Slow rate of growth
 iii. Late metastatic rate
 (c) Mesothelioma
 i. Diffuse neoplasia of the pericardium, pleura, and peritoneum
 ii. Difficult to diagnose without pericardial biopsy and immunohistochemistry
 (d) Other: Lymphoma, thyroid carcinoma, myxoma
 (2) Idiopathic
 (a) Typically middle-aged, large-breed dogs
 (b) Commonly reported breeds: Golden retriever, Saint Bernard, Great Dane
 (3) Infectious
 (a) Bacterial
 (b) Fungal (coccidioidomycosis, nocardia, actinomyces)
 (c) Viral (feline infectious peritonitis)
 (4) Left atrial rupture secondary to chronic degenerative mitral valve disease
 (5) Rodenticide poisoning
 d. Most common causes in dogs
 (1) Idiopathic
 (2) Neoplasia
 e. Most common causes in cats
 (1) CHF
 (2) Feline infectious peritonitis
 3. Clinical signs: Weakness, lethargy, anorexia, weight loss, ascites, syncope, sudden death
 4. Physical examination
 a. Highly suggestive of pericardial effusion
 (1) Muffled heart sounds
 (2) Jugular venous distension
 (3) Weak or varying pulse quality
 b. Arrhythmia
 c. Pulse deficits
 d. Normal to pale mucous membrane color
 e. Ascites
 f. Dyspnea
 D. Diagnosis
 1. Types of effusion
 a. Transudate
 b. Modified transudate
 c. Exudate
 d. Hemorrhagic
 e. Chylous
 2. Echocardiogram
 a. Preferably performed before pericardiocentesis if patient is stable
 b. Anechoic space between the heart and pericardial sac representative of pericardial effusion
 c. Decreased left and right ventricular size
 d. Tamponade: The presence of diastolic or systolic collapse of the right atrium or ventricle
 e. Mass most often associated with the right auricle, right atrium, or aorta
 f. Pleural effusion

3. Electrocardiography
 a. Sinus tachycardia
 b. Small QRS complexes
 c. Electrical alternans: Variations in R wave height
 d. ST segment changes
 e. Ventricular arrhythmias
4. Thoracic radiographs
 a. Normal in dogs with a small volume of effusion
 b. Generalized cardiomegaly with a globoid (spherical) shape
 c. Tracheal elevation
 d. Enlarged caudal vena cava
 e. Pleural effusion
5. Blood pressure: Normal to decreased systolic pressure
6. CBC
7. Coagulation panel if coagulopathy is suspected
8. Fungal serology if infectious cause is suspected

E. Treatment
1. Pericardiocentesis
 a. Intravenous (IV) fluid therapy may improve cardiac output before removing pericardial fluid
 b. Diuretic therapy is contraindicated
 c. Pericardial fluid submitted for cytology and culture
2. Pericardectomy
3. Chemotherapy

F. Prognosis: Variable depending on rate of recurrence. Guarded to poor with hemangiosarcoma

VI. Systemic hypertension
A. Defined as an elevated systemic arterial blood pressure
B. Normal blood pressure is variable depending on age, breed, and anxiety level in a clinical setting. A systolic pressure greater than 160 mmHg is typically considered hypertensive
C. Causes
1. Essential or primary: Rare in dogs and cats
2. Secondary
 a. Renal disease
 b. Endocrine disease
 (1) Hyperadrenocorticism
 (2) Hyperthyroidism
 (3) Diabetes mellitus
 (4) Pheochromocytoma

D. Clinical signs: May be normal. Anorexia, weight loss, exercise intolerance, lethargy, syncope, epistaxis, neurologic signs (seizures)
E. Physical examination
1. Blindness
2. Retinal hemorrhage or detachment
3. Tortuous retinal arteries
4. Systolic or diastolic left heart murmur
5. Examination findings consistent with underlying endocrine or renal disease

F. Diagnosis
1. Blood pressure: Increased systolic or diastolic pressure
2. Thoracic radiographs
 a. Normal in dogs with mild hypertension
 b. Left ventricular enlargement
 c. Left atrial enlargement
 d. Enlarged, tortuous descending aorta
3. Echocardiogram
 a. Normal to increased left ventricular wall thickness
 b. Aortic regurgitation
 c. Left atrial enlargement
4. CBC. Findings consistent with underlying endocrine or renal disease
5. Biochemistry panel. Findings consistent with underlying endocrine or renal disease
6. Thyroid panel (T_4, free T_4 by ED, TSH)
7. Adrenocorticotropic hormone–releasing hormone (ACTH) stimulation test (or other test for hyperadrenocorticism)

G. Treatment: Medical management
1. Antihypertensive medications such as hydralazine, amlodipine, ACE inhibitors
2. Sodium nitroprusside in hypertensive emergencies

H. Prognosis: Favorable with treatment; azotemia and blindness are often permanent

VII. Pulmonary hypertension
A. Defined as an increased pulmonary arterial blood pressure greater than 25 mm Hg systolic and 15 mm Hg diastolic
B. Causes
1. Primary: Rare in dogs and cats
2. Secondary
 a. Respiratory disease
 (1) Chronic tracheobronchitis
 (2) Interstitial lung disease
 (3) Chronic exposure to high altitude
 b. Cardiovascular disease
 (1) Cardiomyopathy
 (2) Mitral valve endocardiosis
 (3) Mitral valve stenosis
 (4) Left-to-right shunting congenital heart disease
 c. Pulmonary thromboembolic disease
 (1) Thrombus: Disseminated intravascular coagulation. Protein-losing renal or GI disease. Hyperadrenocorticism. Chronic corticosteroid administration
 (2) Tumor
 d. Inflammatory disorders: Heartworm disease. Respiratory disease such as bronchitis

C. Clinical signs: May be normal. Cough, dyspnea, anorexia, weight loss, exercise intolerance, lethargy, syncope
D. Physical examination
1. Systolic right heart murmur of tricuspid regurgitation
2. Split second heart sound
3. Gallop
4. Ascites
5. Jugular venous distension
6. Positive hepatojugular reflex

7. Normal to decreased pulse quality
8. Systolic left heart murmur if underlying mitral valve endocardiosis
9. Examination findings consistent with underlying endocrine diseases
10. Rarely peripheral edema

E. Diagnosis
1. Thoracic radiographs
 a. Normal in dogs with mild disease
 b. Right ventricular enlargement
 c. Right atrial enlargement
 d. Left ventricular enlargement
 e. Left atrial enlargement
 f. Enlarged pulmonary artery
 g. Pleural effusion
 h. Evidence of respiratory disease such as peribronchial or interstitial markings
2. ECG
 a. Deep S waves in leads I, II, III, aV_f suggestive of right ventricular enlargement
 b. Tall P waves in lead II suggestive of right atrial enlargement
 c. Right axis deviation
 d. Tall R wave in lead II suggestive of left ventricular enlargement with underlying mitral valve endocardiosis
 e. Wide P wave in lead II suggestive of left atrial enlargement with underlying mitral valve endocardiosis
3. Echocardiogram
 a. Right ventricular enlargement
 b. Right atrial enlargement
 c. Tricuspid regurgitation
 d. Pulmonic regurgitation
 e. Pulmonary artery enlargement
 f. Left atrial or ventricular enlargement with underlying mitral valve endocardiosis
 g. Mitral regurgitation
 h. Heartworms present in the pulmonary artery
4. CBC
 a. Anemia
 b. Findings consistent with underlying endocrine or renal disease or a coagulation abnormality
5. Biochemistry panel
 a. Hypoalbuminemia
 b. Findings consistent with underlying endocrine or renal disease
6. Coagulation panel
7. Urinalysis: Proteinuria

F. Treatment: Medical management
1. Oxygen therapy
2. Identify and treat underlying cause
3. Phosphodiesterase inhibitors such as pimobendan (cardiac related) and sildenafil (non-cardiac related)
4. CHF
 a. Oxygen
 b. Diuretics
 c. Positive inotropic support
 d. Nitroglycerin ointment
 e. ACE inhibitor
 f. Pleurocentesis
 g. Abdominocentesis

G. Prognosis
1. Favorable with mild pulmonary hypertension
2. Guarded to poor with symptomatic moderate to severe pulmonary hypertension

ELECTROCARDIOGRAM (ECG) AND ARRHYTHMIAS

I. Conduction originates in the sinus node and proceeds through the atrioventricular node into the ventricles via the His bundle, right and left bundle branches, and Purkinje fibers

II. Normal heart rate for dogs is 60 to 160 beats/min

III. Normal heart rate for cats is 150 to 240 beats/min

IV. An ECG is used to evaluate heart rate, rhythm, conduction abnormalities, and chamber enlargement patterns

V. Components of an ECG complex
A. P wave represents atrial depolarization
B. PR interval represents atrioventricular nodal conduction
C. QRS complex represents ventricular depolarization
D. T wave represents ventricular repolarization

VI. ECG criteria for chamber enlargement
A. Left atrial enlargement. Wide P wave
B. Left ventricular enlargement. Tall R wave
C. Right atrial enlargement. Tall P wave
D. Right ventricular enlargement
 1. Deep S wave in leads I, II, III, aV_f
 2. Right axis shift

VII. Sinus: Indicates a beat that originates from the sinus node
A. Normal sinus rhythm: Beats originate from the sinus node and have a regular rhythm
B. Sinus arrhythmia: Beats originate from the sinus node and have an irregular rhythm
 1. Caused by increased parasympathetic tone
 2. May be associated with respiratory cycle
 3. Frequently accompanied by a wandering atrial pacemaker, which is a variation in P-wave height
C. Sinus bradycardia: A slow sinus rhythm
D. Sinus tachycardia: A fast sinus rhythm

VIII. Premature beats
A. Supraventricular premature beats (atrial premature contractions or complexes, atrial extrasystoles)
 1. Premature complex
 2. Narrow, upright QRS complex resembling sinus beats
 3. P wave may be different than the sinus beats
 4. Variable PR interval
 5. Noncompensatory pause
 6. Frequently associated with atrial enlargement
B. Ventricular
 1. Premature complex
 2. Wide, bizarre QRS complexes that do not resemble supraventricular beats
 3. P waves may be visualized marching through the complexes

4. Compensatory pause
5. May be cardiac or noncardiac in origin. Noncardiac origin includes the following:
 a. Gastric dilatation volvulus
 b. Splenic or hepatic neoplasia
 c. GI disease
 d. Pancreatitis
 e. Anemia
 f. Hypoxemia
 g. Pain
 h. Electrolyte abnormalities

IX. Bradyarrhythmias
 A. Atrioventricular block
 1. First degree
 a. Prolongation of the PR interval
 b. May be associated with increased parasympathetic tone
 c. Typically resolves with administration of atropine
 2. Second degree
 a. Mobitz type I (Wenckebach)
 (1) Progressive prolongation of the PR interval on consecutively conducted beats followed by P wave with an associated QRS complex
 (2) May be associated with increased parasympathetic tone
 (3) Typically resolves with administration of atropine
 b. Mobitz type II
 (1) Intermittent presence of P waves without associated QRS complexes
 (2) May be associated with increased parasympathetic tone or atrioventricular nodal disease
 (3) Resolves with administration of atropine if it is due to increased parasympathetic tone
 3. Third degree
 a. Complete loss of communication between the atria and ventricles. P waves are present with no association to ventricular escape beats
 b. Typically associated with atrioventricular nodal disease
 c. Will not respond to administration of atropine
 B. Sinus arrest: Loss of sinus node activity
 C. Atrial standstill: Loss of atrial depolarization
 1. Occurs with hyperkalemia associated with urinary obstruction or hypoadrenocorticism
 2. Associated with muscular dystrophy in English springer spaniels

X. Tachyarrhythmias
 A. Supraventricular
 1. Atrial fibrillation: Combination of no P waves, irregularly irregular ventricular rate, and narrow, upright QRS complex resembling supraventricular beats. The most common supraventricular tachyarrhythmia
 2. Atrial flutter: Combination of no P waves, irregularly irregular ventricular rate, narrow, upright QRS complex resembling supraventricular beats, and coarse fibrillatory waves in the baseline give a saw tooth appearance
 3. Atrial tachycardia: Series of atrial premature complexes occurring at a fast heart rate
 4. Treatment
 a. Medications: β-Blockers, calcium channel blockers, digoxin, amiodarone, procainamide, lidocaine
 b. Transthoracic electrical cardioversion may convert atrial fibrillation to a sinus rhythm
 B. Ventricular
 1. Ventricular tachycardia: Three or more ventricular premature beats in a row. Treatment: Lidocaine, procainamide, mexilitine, or β-blockers
 2. Ventricular fibrillation: Loss of organized ventricular activity resulting in cardiac arrest. Treatment: Transthoracic electrical cardioversion
 3. Torsades de pointes: Associated with an initially slow heart rate and prolongation of the QT interval. The resulting ventricular arrhythmia has a cyclic variation in amplitude around the baseline. Treatment: IV magnesium sulfate

XI. Sick sinus syndrome
 A. Characterized by any combination of sinus arrest, sinus tachycardia, supraventricular tachycardia, sinus bradycardia, ventricular escape beats, and atrioventricular block
 B. Common breeds: miniature schnauzer, cocker spaniel, West Highland white terrier, pug
 C. Treatment can consist of pacemaker implantation to prevent bradycardia and antiarrhythmic therapy to prevent tachycardia

XII. Most common reasons for pacemaker implantation
 A. Third-degree atrioventricular block
 B. Second degree type II atrioventricular block
 C. Sick sinus syndrome
 D. Atrial standstill

XIII. Additional ECG abnormalities
 A. Differentials for small QRS complexes
 1. Pericardial effusion
 2. Pleural effusion
 3. Thoracic or pericardial fat
 4. Hypothyroidism
 B. ST segment depression and elevation are associated with myocardial hypoxia
 C. A bundle-branch block is identified by wide QRS complexes preceded by a P wave

MEDICATIONS

I. Diuretics
 A. Useful for preload reduction in dogs with CHF
 B. Differentiated into three classes, depending on where they act on the nephron
 1. Loop diuretics inhibit sodium, potassium, and chloride reabsorption in the thick ascending loop of Henle and are the most potent
 a. Furosemide (IV, IM, subcutaneous, oral)
 b. Adverse effects: Dehydration, azotemia, electrolyte abnormalities

2. Potassium-sparing diuretics inhibit aldosterone in the distal tubule
 a. Spironolactone (oral)
 b. Adverse effects: Dehydration, azotemia, electrolyte abnormalities
3. Thiazide diuretics inhibit the sodium chloride cotransporter in the distal convoluted tubule
 a. Hydrochlorothiazide (oral)
 b. Adverse effects: Dehydration, azotemia, electrolyte abnormalities (Table 12-3)

II. Antiarrhythmic medication (based on Vaughn Williams classification)
 A. Class I antiarrhythmic medications are the sodium channel blockers
 B. Three subclasses
 1. Class 1A
 a. Quinidine (oral)
 (1) Indications: Quinidine is used to manage atrial fibrillation in horses and occasionally in dogs
 (2) Adverse effects: GI upset, proarrhythmia
 b. Procainamide (IV, oral)
 (1) Indications: Supraventricular and ventricular arrhythmias
 (2) Adverse effects: GI upset, hypotension
 2. Class 1B
 a. Lidocaine (IV)
 (1) Indications: Drug of choice for ventricular arrhythmias
 (2) Adverse effects: GI upset, neurologic abnormalities including tremors and seizures
 b. Mexilitine (oral)
 (1) Indications: Ventricular arrhythmias
 (2) Adverse effects: Similar to lidocaine
 3. Class 1C. Flecainide: Not routinely used in veterinary medicine
 C. Class II antiarrhythmic medications are the β-blockers
 1. Mechanism of action: Block β-adrenergic receptors resulting in varying degrees of heart rate reduction (negative chronotropy) and reduction in ventricular contractility (negative inotropy)
 2. Nonselective: Block β-1 and -2 receptors
 a. Propranolol (oral)
 b. Carvedilol (oral)
 3. Selective: Block β-1 receptors
 a. Atenolol (oral)
 b. Esmolol (IV)
 4. Indications: Supraventricular and ventricular tachycardia
 5. Adverse effects: Lethargy, anorexia, bradycardia, atrioventricular block, hypotension, reduction in systolic function resulting in clinical decompensation, and bronchoconstriction with nonselective β-blockers
 D. Class III antiarrhythmic medications are the potassium channel blockers
 1. Mechanism of action: Block potassium channels to prolong the action potential duration
 2. Amiodarone (IV, oral)
 a. Has properties of all four antiarrhythmic classes
 b. Indications: Supraventricular and ventricular arrhythmias
 c. Adverse effects: GI upset, anemia, hepatotoxicity, thyroid dysfunction, proarrhythmia
 3. Sotalol (oral)
 a. Has β-blocking properties
 b. Indications: Supraventricular and ventricular arrhythmias
 c. Adverse effects: Bradycardia, proarrhythmia, hypotension, GI upset
 E. Class IV antiarrhythmic medications are the calcium channel blockers
 1. Mechanism of action: Block the slow L-type calcium channels
 2. Nondihydropyridines affect the sinus and atrioventricular nodes resulting in supraventricular antiarrhythmic properties
 a. Verapamil (IV, oral)
 (1) Indications: Supraventricular arrhythmias
 (2) Adverse effects: Bradycardia, atrioventricular block, hypotension; reduction in systolic function is more profound than with diltiazem and can result in clinical decompensation
 b. Diltiazem (IV, oral)
 (1) Indications: Supraventricular arrhythmias
 (2) Useful when treating atrial fibrillation when used in combination with digoxin
 (3) Adverse effects: Bradycardia, atrioventricular block; hypotension and reduc-

Table 12-3 Effects of Common Cardiac Medication on Potassium

Medication	Potassium Sparing or Wasting
Furosemide	Wasting
Spironolactone	Sparing
Hydrochlorothiazide	Wasting
Enalapril-benazepril	Sparing

tion in systolic function can result in clinical decompensation

3. Dihydropyridines have primarily vascular effects and are not used as antiarrhythmic medications. Amlodipine: See section on vasodilators

F. Digitalis glycosides
1. Mechanism of action: Increased parasympathetic tone to decrease sinus and atrioventricular nodal activity. Additionally inhibits the sodium potassium pump, resulting in an increase in cardiac contractility (positive inotropy)
2. Digoxin (IV, oral)
a. Indications: Supraventricular arrhythmias
b. Adverse effects: GI upset, proarrhythmia (bradycardia, atrioventricular block)
c. Toxicity more likely in the presence of hypokalemia and azotemia
d. Drug interactions with furosemide, verapamil, quinidine, and amiodarone result in digoxin toxicity

III. Positive inotropic medication
A. Indications – Myocardial failure
B. Digoxin (IV, oral)
1. Mechanism of action: Inhibits the sodium potassium pump, resulting in an increase in cardiac contractility
2. Adverse effects: GI upset, proarrhythmia (bradycardia, atrioventricular block)
3. Toxicity is more likely in the presence of hypokalemia and azotemia
4. Drug interactions with furosemide, verapamil, quinidine, and amiodarone result in digoxin toxicity

C. Pimobendan (oral)
1. Mechanism of action: Phosphodiesterase III inhibitor resulting in positive inotropy and vasodilation
2. Adverse effects: Uncommon but could include systemic hypotension
3. Table 12-4

D. Sympathomimetics
1. IV administration
2. Mechanism of action: Bind to β-receptors in the myocardium
a. Isoproterenol: Results in positive inotropy, positive chronotropy, proarrhythmia, and hypotension. Not used routinely in clinical cases
b. Epinephrine: Results in positive inotropy, positive chronotropy, and proarrhythmia. Useful during cardiopulmonary resuscitation
c. Norepinephrine: Results in positive inotropy, positive chronotropy, and vasoconstriction. Not used routinely in clinical cases
d. Dopamine – Results in positive inotropy, vasodilation at low doses, vasoconstriction, positive chronotropy and proarrhythmia at high doses. Not used routinely to treat CHF
e. Dobutamine: Results in positive inotropy, minimal positive chronotropic effect, minimal change in blood pressure, minimal proarrhythmic effect. Useful when treating acute CHF (Table 12-4)

IV. Vasodilators
A. Arteriodilators
1. Hydralazine (oral)
a. Mechanism of action: Elevated vasodilatory prostacyclin in the systemic arterioles
b. Adverse effects: Hypotension, reflex tachycardia, GI upset
2. Amlodipine (oral)
a. Mechanism of action: Dihydropyridine calcium channel blocker acting primarily on systemic arterioles
b. Adverse effects: Hypotension, reflex tachycardia
3. ACE inhibitors (oral)
a. Mechanism of action: Inhibits ACE, which decreases angiotensin II circulation. Angiotensin II is a potent vasoconstricting agent and increases sodium and water retention
b. Not as potent a vasodilator as hydralazine and amlodipine are
c. Examples: Enalapril, benazepril, lisinopril, ramipril, captopril
d. Adverse effects: Azotemia, hyperkalemia. Systemic hypotension occurs infrequently

Table 12-4 Inotropic and Chronotropic Effects of Various Cardiac Medications

Medication	Inotropic Effects	Chronotropic Effects
Calcium channel blockers (e.g., diltiazem)	Negative	Negative
β-Blockers (e.g., atenolol)	Negative	Negative
Digoxin	Positive	Negative
Pimobendan	Positive	None

4. Sodium nitroprusside (IV)
 a. Useful in acute hypertensive emergencies
 b. Arterial and venodilator
 c. Mechanism of action: Release of nitric oxide results in vasodilation
 d. Adverse effects: Hypotension, cyanide toxicity with prolonged use

B. Venodilators: Nitroglycerine ointment (topical)
 1. Indication – Acute CHF
 2. Adverse effects – Hypotension, build up tolerance with prolonged use

Supplemental Reading

Kittleson MD, Kienle RD. *Small Animal Cardiovascular Medicine.* St Louis, 1998, Mosby.

Smith FWK, Keene BW, Tilley LP. *Rapid Interpretation of Heart and Lung Sounds*, 2nd ed. St Louis, 2007, Saunders.

Tilley LP, Smith FWK, Oyama M, Sleeper MM. *Manual of Canine and Feline Cardiology*, 4th ed. St Louis, 2008, Saunders.

13 CHAPTER

Dermatology

Elizabeth Rustemeyer May

GENERAL ASSESSMENT OF THE DERMATOLOGY PATIENT

I. Signalment: Age, breed, sex, color
 A. Age: Congenital-hereditary conditions
 B. Breeds: Terriers, atopy; American cocker spaniels, seborrhea
 C. Sex: Reproductive hormone endocrinopathies
 D. Color: Color-dilution alopecias

II. Primary complaint: What is the owner's primary reason for consulting a veterinarian? Be sure to address this via diagnostics, treatments, and client education

III. History
 A. A thorough and accurate history provides useful information that will aid in diagnosis
 B. Obtain history in chronological order: Are the symptoms seasonal or nonseasonal? Which symptoms were present first—the itching or the alopecia? Have things changed since the symptoms were initially noticed?

IV. Physical examination
 A. Properly using the correct dermatologic terms for lesions is crucial, as is a thorough physical examination. Be sure to examine the ears, feet, mucous membranes, lymph nodes, claws, and footpads. Note whether the lesions appear symmetrical or nonsymmetrical
 B. Differentiate between primary and secondary lesions
 C. Primary lesions: Main clinical sign directly caused by a disease process
 1. Macule: Circumscribed flat spot up to 1 cm in diameter characterized by a change in color
 2. Patch: A macule greater than 1 cm in diameter; not palpable
 3. Papule: A solid elevation up to 1 cm in diameter. This represents infiltration of cells, edema, or hypertrophy of the epidermis. It can be palpated and is often erythematous
 4. Plaque: Larger flat- topped elevation formed by extension or collection of papules
 5. Pustule: Small circumscribed elevation of skin filled with pus
 6. Vesicle: Circumscribed lesion up to 1 cm filled with clear fluid. These are rare and fragile. They are intraepidermal or subepidermal. Most are associated with autoimmune skin diseases (small animal) or viral diseases (large animal)
 7. Bulla: A vesicle larger than 1 cm in diameter
 8. Wheal: Circumscribed, raised lesion consisting of edema that appears in minutes to hours. The lesion will pit with digital pressure
 9. Nodule: A small circumscribed solid elevation greater than 1 cm in diameter that results from massive infiltration of inflammatory or neoplastic cells into the dermis or subcutaneous (SC) tissue
 10. Tumor: Neoplastic enlargement of any structure of the skin
 11. Cyst: Epithelial lined cavity filled with fluid or solid material, such as keratin or sebaceous secretions
 D. Primary or secondary lesions. Primary if main clinical sign is directly caused by the disease process, secondary if not specifically caused by the disease process but secondary to self-trauma or inflammation
 1. Alopecia: Baldness or absence of hair from an area of skin where it is normally present. This is a primary lesion in endocrinopathies but a secondary lesion to pyoderma
 2. Scale: Accumulation of loose fragments of the stratum corneum (keratinocytes). This is a primary lesion in seborrhea but secondary to self-trauma or inflammation
 3. Follicular casts: Accumulation of follicular material adhered to the hair shaft
 4. Crust: Dried exudate made up of serum, white blood cells (WBCs), red blood cells, and keratin
 5. Hyperpigmentation: Increased epidermal or dermal melanin
 6. Hypopigmentation: Loss of epidermal melanin
 7. Comedo (comedones): Dilated hair follicle filled with keratin and sebaceous secretions (blackhead)
 E. Secondary lesions: Not specific for the underlying disease process; may be caused by self-trauma or other inflammatory processes
 1. Epidermal collarettes: Circular rim of loosely attached keratin (scale); usually indicative of a staphylococcal infection
 2. Scar: An area of fibrous tissue that has replaced damaged dermal or SC tissue
 3. Excoriation: Erosion or ulcer formed by the removal of superficial epidermis in a linear fashion by scratching, biting

4. Erosion: Interruption of the epidermis that does not penetrate the basement membrane zone; will heal without scarring
5. Ulcer: Deeper interruption of the epidermis that exposes the underlying dermis; will heal with scarring
6. Lichenification: "Elephant skin"; thickened, firm skin with exaggerated superficial skin markings; results from constant friction or inflammation
7. Hyperkeratosis: Increased thickness of the stratum corneum
8. Fissure: Linear defect into the epidermis or dermis caused by disease or injury
9. Callus: Thickened hyperkeratotic lichenified area over bony prominences as a result of pressure or chronic low-grade friction

V. Differential diagnosis: Separate each problem and list differential diagnoses for each
VI. Diagnostic plan: Each diagnostic test is chosen to rule in or rule out the differential diagnoses listed for each problem
VII. Therapeutic plan: Formulation of a plan based on results from the thorough physical examination as well as results from each diagnostic test performed. Avoid "shotgun" therapy with multiple classes of drugs (i.e., both antibiotics and steroids)
VIII. Client education: A crucial portion of treating the dermatologic patient. Clear, concise instructions and explanations will ensure that the owner follows directions as expected

STRUCTURE AND FUNCTION OF THE SKIN

I. Skin structure
 A. Epidermis
 B. Dermal-epidermal junction
 C. Dermis
 D. Hypodermis or subcutis (SC tissue)
 E. Epidermally derived appendages
 1. Pilosebaceous structures
 2. Eccrine sweat glands
 3. Claws
II. Epidermis
 A. Stratum corneum
 1. Several layers of anuclear cornified cells separated by lipids
 2. Major barrier to the outside world
 3. Hyperkeratosis describes thickening of this layer.
 B. Stratum granulosum
 1. One layer thick in haired skin; additional layers in thinly haired skin
 2. Granules in this layer contribute to formation of the intercellular lipids in the stratum corneum.
 C. Stratum spinosum
 1. Variable number of layers, typically one to three layers in haired skin
 2. The beginning of cellular differentiation (keratinization) occurs here
 D. Stratum basale
 1. One layer of columnar cells and melanocytes
 2. The site of cell division and production of daughter cells to supply the upper layers of the epidermis
 3. Attached to the basement membrane zone
III. Epidermal turnover time: 21 to 28 days in most species. Some diseases can shorten cell turnover time, thus forcing keratinocytes to mature too quickly, resulting in seborrhea
IV. Cells of the epidermis
 A. Keratinocytes
 1. Most numerous
 2. Produce keratin—involved in the process of keratinization
 3. Produce lipid for the barrier layer
 4. Produce important cell-signaling cytokines, thus involved in the immune response to allergy or injury
 B. Melanocytes
 1. Basal layer of the epidermis
 2. Produce melanin pigment granules
 C. Langerhans cells: Responsible for immune surveillance and antigen presentation, especially important in the development of allergies
 D. Other cells
 1. Merkel cell
 2. Inflammatory cells (neutrophils, eosinophils, lymphocytes, etc.) when skin is diseased
V. Hair follicles and hair
 A. Phases of growth
 1. Anagen = hair growth phase
 2. Catagen = transition phase
 3. Telogen = hair resting phase; most of an animal's hair is in this phase
 B. Hair growth is affected by the following:
 1. Hormones. Thyroid hormones, cortisol, sex hormones
 2. Nutrition
 3. Day length
 C. Types of hair follicles
 1. Simple = 1 hair per hair follicle opening. Cattle and horses have this type of follicle
 2. Compound = Multiple hairs from one hair follicle opening. Dogs, cats, sheep, and goats have this type of follicle
VI. Epidermal glands
 A. Sebaceous glands. Sebum secretion affected by
 1. Sex hormones
 2. Thyroid hormone
 3. Cortisol
 4. Malnourishment
 5. Fatty acid deficiency
 B. Sweat glands
 1. Apocrine glands
 a. Secretion empties into the hair follicle
 b. Most domestic animals have this type of gland throughout the body
 2. Eccrine glands
 a. Secretion empties onto the surface of the skin ("sweating")
 b. Found on the footpads of dogs and cats
VII. Dermis
 A. Main support structure for the epidermis
 B. Thickest part of the skin

C. Made up of collagen, elastic fibers, some muscles (arrector pili muscles), blood vessels, and nerves

VIII. Functions of the skin
- A. Barrier: Physical protection from the environment, including regulation of water loss as well as protection from microbial invasion
- B. Communication
 1. Senses of touch, pain, itch
 2. Immune system communicates from the skin to the lymphatic system
- C. Temperature regulation
 1. The hair coat provides warmth
 2. Blood vessels of the skin dilate or constrict to allow for cooling or preservation of heat
 3. Sweat
 4. SC fat
- D. Secretion. Sweat, phermones, lipid barrier
- E. Storage. Electrolytes, water, vitamins, protein, carbohydrates
- F. Pigmentation. Ultraviolet light protection
- G. Vitamin D production

FOLLICULITIS

I. Inflammation of the hair follicle. The clinical lesion reflects this and is typically a circular area of alopecia with scale and hyperpigmentation. Papules, pustules, and epidermal collarettes are also associated with folliculitis

II. The three main differential diagnoses for folliculitis include bacterial pyoderma, demodicosis, and dermatophytosis
- A. Demodicosis
 1. Inflammatory parasitic skin disease caused by the follicular mite *Demodex canis* or two other newly recognized variants
 2. *D. canis* found in small numbers in healthy normal dog skin
 3. In the *disease* state, these mites are present in much larger numbers than in normal individuals
 4. Demodicosis can be very difficult to cure and thus very frustrating for the owner
 5. The demodex mite spends its entire life on the skin of its host
 6. Four stages
 a. Fusiform egg
 b. Six-legged larvae
 c. Eight-legged nymph
 d. Eight-legged adult (Figure 13-1)
 7. Life cycle takes 20 to 35 days
 8. Mites spread from bitch in the first 3 days of life
 9. Nursing provides direct contact for transmission; therefore, muzzle and forelegs are first sites of infestation
 10. *Not* a contagious disease; mites are difficult to transfer to dogs older than a few days
 11. There is an assumed weak link in the immune system of dog with demodicosis
 12. The current belief is that these dogs have a T-cell function abnormality



Figure 13-1 *Demodex canis.* (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice,* 3rd ed. St Louis, 2006, Saunders.)

- B. Localized demodicosis
 1. Age younger than1 year, usually 3 to 6 months
 2. Lesions consist of localized areas of alopecia, usually minimal pruritus (mild clinical disease)
 3. The *face,* especially the periocular and commissures of mouth, and forelegs are most commonly affected areas
 4. 90% resolve spontaneously in 6 to 8 weeks
 5. Optimize health (deworm, improve plane of nutrition)
 6. This is *not* genetic or a genetic defect
 7. Reexamine and rescrape in 3 weeks
 a. If increase in numbers of mites, new lesions, lymphadenopathy—may be developing *generalized* condition
 b. A small number of localized cases progress to generalized demodicosis
- C. Generalized demodicosis
 1. Juvenile onset (3 to 12 months)
 a. Usually starts as localized lesions, which progress to generalized lesions affecting all parts of the body if not treated adequately or do not resolve spontaneously
 b. Most animals appear to have a hereditary disposition
 2. Adult onset (usually older than 5 years)
 a. May be associated with internal disease, malignancy, or chronic corticosteroid use
 b. Can be associated with hypothyroidism and spontaneous or iatrogenic hyperadrenocorticism
 c. If no cause is found, the odds of successfully treating are decreased
 3. Clinical signs of generalized demodicosis
 a. Large areas of alopecia, usually nonpruritic
 b. Major differentials include pyoderma and dermatophytosis
 c. Mild to severe erythema
 d. Usually skin becomes gray or hyperpigmented from chronic inflammation as well as large groups of comedones
 (1) Often there is secondary pyoderma—superficial or deep, usually caused by

Staphylococcus pseudintermedius, *Proteus* spp., or *Pseudomonas* spp.
(2) Clinically looks like papules, pustules, crusts, exudation (nodular form in bulldogs)
(3) A peripheral lymphadenopathy is often present if a pyoderma is present
(4) Depending on the severity of the secondary pyoderma, the animal may be systemically ill

4. Chronic demodectic pododermatitis
 a. This is a form of generalized demodicosis
 b. May have persistent foot lesions after therapy for generalized demodicosis
 c. Demodicosis may only have been present on the feet
 d. Often refractory to therapy
5. Otitis. Demodicosis may occasionally occur as an erythematous, ceruminous otitis externa, especially in cats

D. Diagnosis (Figure 13-2)
1. *Deep* skin scrapings or hair plucks (trichograms) to visualize mites
2. Squeeze the affected area to extrude mites from the hair follicles
3. Take multiple scrapings, a minimum of three scrapings from lesional skin

E. Therapy
1. Do not use corticosteroids in these patients!
2. Localized demodicosis
 a. Spontaneous remission in 90% of cases so treatment not usually needed; avoid using Amitraz (Mitaban dip) for this type of demodicosis
 b. Benzoyl peroxide gel or shampoo for the follicular flushing action and to prevent secondary bacterial infections
 c. Improve nutrition; remove intestinal parasites or other stress factors (fecal and heartworm test)
 d. Recheck these animals in 3 to 4 weeks; if lesions are spreading or mite counts are increasing, the disease is progressing toward becoming generalized
3. Generalized demodicosis
 a. Correct any nutritional, parasitic, or other concurrent problems
 b. Dogs with adult-onset demodicosis should receive full workups to look for underlying (immunosuppressive) diseases; that is, get a minimum database (Complete blood cell count, serum biochemistries, urinalysis, heartworm and fecal checks, and usually thyroid and Cushing evaluation)
 c. Start on appropriate antibiotic therapy based on culture and sensitivity. Use a bactericidal antibiotic for 3 to 6 weeks
 d. Bathe the dog with an antibacterial and keratolytic shampoo (e.g., benzoyl peroxide) to open the hair follicles and remove crusts before applying Mitaban dip if using
 e. Mitaban dips
 (1) Mitaban used every 2 weeks is the only Food and Drug Administration (FDA)-approved treatment for canine demodicosis
 (2) Dipping weekly improves the efficacy of Mitaban, but it is important to realize that this is an off-label use of the product
 (3) Amitraz is a monoamine oxidase inhibitor (MAOI). Do not dip if the dog is taking Anipryl or other MAOI inhibitors. Antidote for Mitaban is yohimbine
 (4) Monitor response to therapy with monthly skin scrapings *Continue dipping 1-2 months beyond two negative skin scrapings 1 month apart*
 (5) Dogs should not be stressed while on this therapy. Female dogs should be spayed when the disease is under control because their estrus cycle may cause a relapse of the disease as well as to prevent pyometra and reduce the risk of mammary neoplasia
 f. Ivermectin
 (1) This is *not* an FDA-approved treatment
 (2) Bovine injectable ivomec (1% solution = 10 mg/mL)
 (3) Treatment dose is much higher than the standard Heartgard dose. *Use only in dogs proven negative for heartworms!*
 (4) *Use caution when considering use in collies, shelties or their crosses, or Old English sheepdogs especially, even those that have been tested for the mdr-1 gene deletion.*
 (5) Reserve this treatment for Mitaban failures or if Mitaban is not a feasible treatment
 (6) Side effects: Mydriasis, ataxia, coma, and death



Figure 13-2 Skin scrape. For deep skin scrapes, once capillary oozing is initiated, the skin is usually squeezed before a final scrape is performed to collect the material. (From Medleau L, Hnilica KA. *Small Animal Dermatology: A Color Atlas and Therapeutic Guide,* 2nd ed. St Louis, 2006, Saunders.)

g. Milbemycin (Interceptor)
(1) This is *not* an FDA approved treatment
(2) Treatment dose is higher than the standard dose for heartworm prevention. *Use only in dogs proven negative for heartworms!*
h. Client Education: Generalized demodicosis
(1) Guarded prognosis
(2) Long course of therapy
(3) Juvenile-onset cases *should not be bred!*

F. Feline demodicosis
1. *Demodex cati:* Follicular mite similar to *Demodex canis* except it is smaller and the ova are slim and oval, rather than spindle-shaped
2. Localized form
a. Lesions are variably pruritic alopecic areas affecting the nose, eyelids, and periocular skin
b. Erythema and scaling may also be present
c. Ceruminous otitis with demodex mites present may be seen without other lesions
3. Generalized form
a. Similar to localized except more body regions are affected
b. Generalized form usually associated with systemic disease and immunodeficiency state
4. Diagnosis
a. Skin scrapings
b. Minimum database for generalized disease, including feline leukemia virus and feline immunodeficiency virus testing
5. Differential diagnoses
a. Dermatophytosis
b. Pyoderma (rare in cats)
c. Causes of miliary dermatitis
d. Causes of pruritus
6. Treatment
a. Localized form = lime sulfur spray or dip
b. Generalized form
(1) Dependent on presence of underlying disease
(2) A consistent successful therapy has not been reported
(3) Weekly lime sulfur dips
(4) Treat underlying disease
7. *Demodex gatoi*
a. Not a follicular mite; lives in the stratum corneum
b. Broad blunted abdomen rather than a slim elongated one
c. This is a contagious (to other cats) and pruritic mite
8. Diagnosis
a. Broad superficial skin scrapings
b. Negative skin scrapings do not rule out *D. gatoi* as a differential diagnosis in a pruritic cat
9. Treatment
a. 6 weekly lime sulfur dips
b. Treat all cats in the household (i.e., all in-contact cats)

G. Pyoderma
1. Bacterial folliculitis and furunculosis are very common in dogs
2. Less common in cats
3. Secondary to an underlying disease process, usually an allergic disease or endocrinopathy
4. Most commonly isolated organism is *Staphylococcus pseudintermedius*
5. Pyoderma classifications
a. Surface pyoderma
(1) Erosion with secondary colonization of surface only
(2) Usually secondary to self-trauma
b. Superficial pyoderma
(1) Restricted to the stratum corneum or opening of hair follicles
(2) Papules, crusted papules, pustules, epidermal collarettes
c. Deep pyoderma
(1) Infections of the deeper region of the hair follicle resulting in rupture of the hair follicle (furunculosis) with extension into the dermis and subcutis
(2) Nodules with draining serosanguineous fluid
6. Treatment
a. Surface pyoderma
(1) Clip and clean lesion with dilute chlorhexidine
(2) Avoid occlusive ointments
(3) Topical antipruritics
b. Superficial pyoderma
(1) Oral antibiotics
(a) Cephalosporins (such as cephalexin or Clavamox) 22 to 33 mg/kg every 12 hours for a minimum of 21 days
(b) Continue therapy for a minimum of 7 days beyond complete clinical remission of lesions
(2) Topical antimicrobials. Chlorhexidine or benzoyl peroxide containing shampoos every 2-3 days
(3) Avoid steroids
c. Deep pyoderma
(1) Oral antibiotics for 4 to 8 weeks; treat for at least 14 days beyond clinical remission
(2) Base antibiotic choice on culture and sensitivity results
(3) Hydrotherapy and topical antimicrobial shampoos
7. Dermatophytosis
a. Fungal organisms invade keratinized structures
b. This can be a self-limiting disease, dependent on the immune status of the host
c. These infections are zoonotic
d. This is *not* a common infection in dogs, but it is *very common* in cats
e. Transmission via contact with an infected host, fomite, or contaminated environment
f. Clinical signs
(1) Minimal to extensive inflammation with scaling and alopecia

(2) Fungal kerions (dermatophytic furunculosis) can also occur
g. *Microsporum canis* is the most commonly isolated species. Infections can also be caused by *Microsporum gypseum* or *Trichophyton mentagrophytes*
h. Cats can be asymptomatic carriers
i. Treatment
(1) Single lesions: Clip and treat with topical antifungal agents. *Avoid combination products containing corticosteroids!*
(2) *Cats require whole body treatments!* Do not spot-treat cats
(3) Multiple lesions; weekly whole-body treatments required
(a) Lime sulfur dip
(b) Chlorhexidine
(c) Miconazole or ketoconazole shampoos
(d) Systemic therapy
i. Oral ketoconazole or itraconazole for dogs
ii. Oral itraconazole or terbinafine for cats
iii. Griseofulvin is also used but has many side effects
(e) Treat for 2 weeks beyond clinical cure and two negative fungal cultures 1 week apart
(4) Environmental decontamination is also important

ENDOCRINE AND ALOPECIC DERMATOSES

I. Alopecia is usually symmetrical and bilateral sparing the head and extremities. This is a noninflammatory alopecia
II. Endocrine alopecias are not common in the cat; look for pruritus as a cause for this type of alopecia in the cat
A. The hair coat is dull and dry and easily epilated with failure to regrow following clipping
B. Skin can be hyperpigmented
C. Seborrhea present
D. Comedones present
E. Secondary bacterial or yeast infections are common. These conditions are nonpruritic unless infections are present
F. Ceruminous otitis externa a common sequela
III. Hypothyroidism
A. Medium- to large-breed dogs
B. Frequently middle-aged dogs; however, high-risk breeds with autoimmune thyroiditis can be diagnosed at a younger age
C. General clinical signs
1. Mental dullness
2. Lethargy
3. Obesity without increased food intake
4. Exercise intolerance
D. Dermatologic clinical signs
1. Alopecia
2. Alopecic "rat" tail
3. Hair loss in areas of friction or wear (collar, harness, over pressure points where the dog lays down, etc.)
4. Loss of guard hairs with retention of under coat
5. Myxedema: Increased skin thickness. Tragic facial expression
6. Recurrent pyoderma or otitis externa
E. Diagnosis and treatment: See small animal endocrinology section
III. Hyperadrenocorticism
A. Middle-aged to older dogs
B. Dermatologic clinical signs
1. Cutaneous atrophy (thin epidermis and dermis) with prominent blood vessels
2. Calcinosis cutis
3. Poor wound healing
4. Recurrent *nonpruritic* pyoderma. "Self-medication" with endogenous cortisol
5. Comedones a frequent finding
6. Bruising or petechia noted in some cases following venipuncture
C. Diagnosis and treatment: See small animal endocrinology section
IV. Sex hormone dermatoses
A. Hyperestrogenism
1. Estrogen source: Cystic ovaries or testicular tumors (Sertoli cell tumor)
2. Iatrogenic via estrogen supplementation for urinary incontinence
3. Females
a. Can have enlarged nipples or vulva in addition to a noninflammatory alopecia
b. Irregular heat cycles
4. Males: Feminization
B. Hyperandrogenism
1. Usually from testicular tumors
2. Hyperplasia of perianal and tail glands
V. Alopecia X (follicular arrest)
A. Not associated with systemic illness
B. Common in poodles, Pomeranians, plush-coated breeds
C. Progressive alopecia with hyperpigmentation of the skin
D. Diagnosed by ruling out other endocrine alopecias
VI. Cyclic flank alopecia
A. Truncal alopecia that occurs seasonally and is typically seen in boxers, English bulldogs, Airedales
B. Usually occurs during the winter months with hair regrowth in the warmer months
VII. Color-dilution alopecia
A. Associated with diluted coat colors
B. Abnormal melanization resulting in a weak hair shaft that breaks with minimal trauma

PRURITIC SKIN DISORDERS

I. Parasitic disorders
A. Flea allergy dermatitis
1. Major cause of skin disease in dogs
2. Most common cause of pruritus in cats

3. *Ctenocephalides felis*: Common flea of dogs and cats
4. Thought to be a hypersensitivity reaction to flea saliva
5. Reaction pattern is due to both type I and type IV hypersensitivity reactions
6. Clinical signs
 a. Dogs
 (1) Pruritus
 (2) Tail-head region extending cranially on the dorsum
 (3) Inner and caudal thighs
 (4) Flexures of the elbows
 (5) Typically a primary papular eruption
 (6) Secondary pyoderma is extremely common due to self-trauma associated with pruritus
 b. Cats
 (1) Miliary dermatitis
 (2) Commonly affecting the neck, head, and tail base
 (3) Can be generalized
 (4) May only see alopecia with self-trauma/excessive grooming
7. Diagnosis
 a. Compatible clinical signs
 b. Presence of fleas or flea dirt
 c. Presence of tapeworm segments
 d. Positive reaction to flea saliva with intradermal injection
 e. This condition cannot be ruled out with the absence of fleas; an aggressive flea control program must be instituted in order to rule out this condition
8. Treatment
 a. Eliminate the flea exposure. Adulticidal plus larvacidal or ovacidal flea control products
 b. Control pruritus and treat secondary infections with appropriate antibiotic therapy

B. Scabies
1. *Sarcoptes scabiei* var. canis mite
2. Species varieties are host-specific but short-lived infestation can occur following transmission to a host of a different species (i.e., dog to human). *Extremely contagious between same species animals by direct contact!*
3. Epidermal burrowing mite
4. Entire life cycle spent on the host
5. Life cycle is 17 to 21 days
6. Clinical signs
 a. *Extremely* pruritic
 b. Mites can be difficult to find with superficial skin scrapings
 c. Ear margins, lateral hocks and elbows, ventral abdomen, chest
 d. Lesions secondary to self trauma: Crusts, excoriations, lichenification
7. Diagnosis
 a. This condition can mimic allergic skin disease
 b. Multiple superficial skin scrapings (Figure 13-3)
 c. Response to therapy is often diagnostic

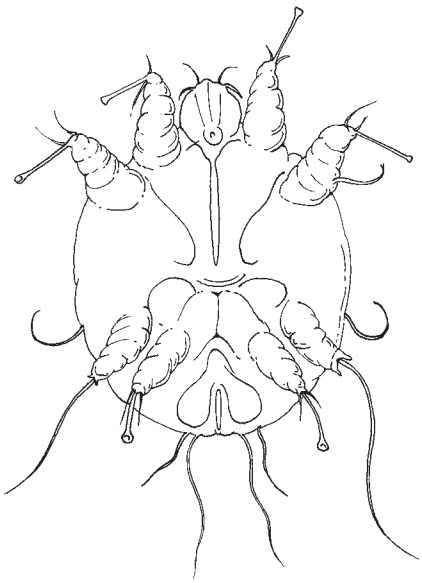


Figure 13-3 Sarcoptes scabiei. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

8. Treatment
 a. Systemic therapy
 (1) Revolution (selamectin)
 (2) Ivermectin SC or orally (avoid use in at-risk breeds or dogs with heartworm disease)
 (3) Interceptor (milbemycin)
 b. Topical therapy: Lime sulfur dip (LymDip); this is both antiparasitic and antipruritic
 c. Treat all in-contact dogs

C. Pediculosis (lice infestation)
1. Lice are species specific
 a. *Linognathus setosus*—dog-sucking louse
 b. *Trichodectes canis*—dog-biting louse
 c. *Felicola subrostratus*—cat-biting louse
2. Transmitted via direct contact
3. Easily diagnosed with direct visualization or tape cytology and microscopic examination
4. Treatment
 a. Most flea-control products will kill lice
 b. Treat all in-contact animals

D. Trombiculosis (chigger infestation)
1. Adults are free living, but the bright orange colored larvae will cause pruritus
2. Seasonal distribution: Spring-fall
3. Transmitted via direct contact with vegetation
4. Pruritus and lesions typically associated with body areas in contact with leaf matter/vegetation
5. Diagnosis by visualization of the mites
6. Treatment
 a. Frontline (fipronil) spray
 b. Most flea sprays or dips are also effective

E. Cheyletiellosis (walking dandruff)
1. Infects dogs, cats, and rabbits
 a. *Cheyletiella yasguri*
 b. *Cheyletiella blakei*
 c. *Cheyletiella parasitovorax*

2. These mites are very large with large pinching mouthparts
3. Highly contagious
4. Clinical signs
 a. Mild-moderate pruritus
 b. Excessive scaling (seborrhea), especially along the dorsum
5. Diagnosis: Broad superficial skin scrapings
6. Treatment
 a. Treat all animals
 b. Environmental decontamination
 c. Frontline (fipronil) spray
 d. Revolution (selamectin)
 e. Lime sulfur dip (LymDip)
7. Can cause intense pruritus in humans

F. Notoedric mange: *Notoedres cati*
1. Sarcoptiform mite
2. Highly contagious among cats via direct contact
3. Severe pruritus of the head and neck
4. Diagnosed by superficial skin scrapings; mites are easy to find compared with the canine scabies mite
5. Treatment
 a. Treat all in-contact cats
 b. Lime sulfur dip (LymDip)
 c. Revolution (selamectin)
 d. Ivermectin SC or orally

II. Infectious disorders

A. *Malassezia* dermatitis (Figure 13-4)
1. Secondary yeast infections are extremely common and intensely pruritic
2. This condition is always secondary to another underlying condition
3. Caused by *Malassezia pachydermatis*
4. Clinical signs
 a. Intense pruritus
 b. Skin is lichenified and hyperpigmented
 c. Affects the axilla, groin, ventral neck, and abdomen in particular (any moist warm area)

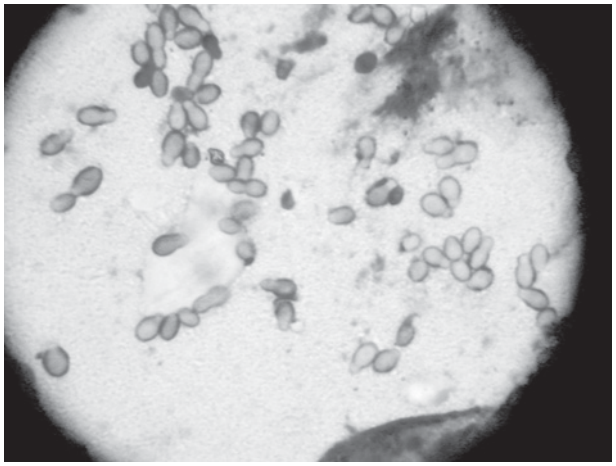


Figure 13-4 Cytology. Microscopic image of *Malassezia* yeast as viewed with a 100× (oil) objective. (From Medleau L, Hnilica KA. *Small Animal Dermatology: A Color Atlas and Therapeutic Guide,* 2nd ed. St Louis, 2006, Saunders.)

5. Diagnosis
 a. Demonstrated organisms on cytology
 b. Compatible clinical signs
6. Treatment
 a. Topical or oral antifungal agents
 b. Antiseborrheic shampoos
 c. Address the underlying cause

B. Staphylococcal pyoderma. See folliculitis

III. Allergic disorders

A. Atopy (atopic dermatitis)
1. Inherited predisposition for the development of hypersensitivities to environmental allergens associated with the production of allergen specific immunoglobulin E (IgE) antibodies
2. Type I hypersensitivity disorder
3. Allergen exposure is thought to be mostly percutaneous; previously inhalation was believed to be the main route of exposure
4. Allergic animals respond to allergen exposure by producing more IgE than a non allergic animal produces
5. Clinical signs typically noted between 1 and 3 years of age
 a. Development of clinical signs requires a second exposure (the challenge) following the initial exposure (sensitization)
 b. Allergen-specific IgE is produced in response to exposure to a previously encountered allergen
 c. Allergen-specific IgE cross-links receptors on mast cells causing degranulation of mast cells and resulting in clinical signs of atopy
6. Clinical signs
 a. Seasonal to nonseasonal pruritus
 b. Typically, face and feet are primarily affected, but these animals can be pruritic in multiple body regions
 c. Chronic otitis externa
 d. Most lesions secondary to self-trauma
 e. Secondary bacterial and yeast infections are extremely common
7. Diagnosis
 a. Pruritus is the hallmark of this disease
 b. Rule out other pruritic causes of skin disease
 c. This is a diagnosis of exclusion
 d. Allergy testing (intradermal or serum testing) is used to determine what the animal is allergic to, not to diagnose atopy
8. Treatment
 a. Avoid the allergen if possible (house dust mite)
 b. Hyposensitization vaccine therapy
 c. Corticosteroids are very effective when used correctly and judiciously
 d. Antihistamines can be used in combination with fatty acids or corticosteroids in order to use lower doses of corticosteroids in some animals
 e. Topical antipruritic and bathing therapy will help decrease allergen exposure
 f. Cyclosporine

B. Adverse reaction to food (food allergy)
 1. Mechanism of disease is not currently known
 2. Typically caused by the protein source in the diet and rarely occurs following a change in diet
 3. Clinical signs
 a. Nonseasonal pruritus
 b. Variable response to corticosteroids
 c. Lesions secondary to self-trauma
 d. Secondary yeast and bacterial skin and ear infections very common
 e. Some animals will also have gastrointestinal (GI) signs
 f. Can occur in animals of any age
 4. Diagnosis
 a. Elimination diet trial
 b. Decrease in pruritus of 50% or more
 c. Diagnosis confirmed by increase in pruritus with food challenge
 5. Treatment
 a. Avoid the offending dietary allergen
 b. Some animals will respond to antihistamine or fatty acid therapy
 c. Corticosteroids or cyclosporine can be considered but less successful with food allergy versus atopy
 d. Topical antipruritic therapy
 e. Control secondary infections

C. Contact dermatitis
 1. Rare cause of skin disease
 2. Typically occurs in thinly haired body regions because hair provides excellent protection
 3. Cell mediated hypersensitivity reaction (type IV) requiring prior sensitization to the allergen
 4. Clinical signs
 a. Mild to moderate pruritus
 b. Secondary lesions and pyoderma from self-trauma
 5. Diagnosis
 a. Rule out other causes via history, clinical signs, distribution of lesions
 b. Identify substances to perform patch testing or a challenge with based on environmental history
 6. Treatment
 a. Avoid the allergen
 b. Topical corticosteroids if required
 c. Treat the secondary bacterial infection if present
 d. Pentoxifylline administered orally

D. Irritant contact dermatitis
 1. Considered an inflammatory reaction to an irritating substance rather than an immunologic reaction like contact allergy
 2. Much more common than contact allergy
 3. Irritating substances associated with irritant contact dermatitis include acids, detergents, insecticides
 4. Clinical signs
 a. Thinly haired areas
 b. May be painful rather than pruritic
 5. Diagnosis is based on history and physical examination
 6. Treatment
 a. Remove the irritating substance by bathing
 b. Avoid the irritating substance

KERATINIZATION AND METABOLIC SKIN DISORDERS

I. Keratinization disorders
 A. Primary keratinization disorders
 B. Primary idiopathic seborrhea
 1. Hereditary or genetic tendency
 2. Young age of onset
 3. Idiopathic form is most common
 4. Cocker spaniels, springer spaniels, West Highland white terriers
 5. Clinical signs
 a. Excessive dry or greasy scale
 b. Malodor
 6. Diagnosis
 a. Signalment and clinical signs
 b. Histopathology
 c. Response to treatment
 7. Treatment
 a. Topical antiseborrheic shampoos and rinses
 b. Vitamin A therapy or synthetic retinoid therapy
 C. Schnauzer comedo syndrome
 1. Primary localized keratinization disorder
 2. Adult onset
 3. Multiple plugged hair follicles along the dorsum; secondary bacterial infections are common
 4. Treatment: Topicals that address the follicular seborrhea as well as bacterial component
 D. Feline acne
 1. Idiopathic localized primary keratinization disorder
 2. Secondary infections common in area with abundant sebaceous secretions
 3. Treatment: Oral with or without topical antibiotic therapy, topical antiseborrheic agents
 E. Secondary keratinization disorders
 1. Common
 2. Secondary to any allergic or endocrine disorder
 3. Address the underlying cause to eliminate clinical signs

II. Zinc deficiency
 A. Nordic breeds have an inherent inability to absorb zinc from the GI tract
 B. Any breed can demonstrate clinical signs if consuming foods that bind zinc in the GI tract and prevent absorption
 1. Plant-based proteins (e.g., corn or soy protein)
 2. Excess dietary calcium supplementation
 C. Clinical signs
 1. Crusting and ulceration on the face and footpads
 2. Animals may also be pyrexic and anorexic
 D. Diagnosis
 1. Signalment, history, and clinical signs
 2. Histopathology

E. Treatment
1. Amino acid complexed zinc supplementation
2. Some cases require corticosteroid therapy as well
3. Avoid food sources known to bind zinc in the GI tract

III. Hepatocutaneous syndrome
A. Cutaneous manifestation of end-stage liver disease
B. Associated with glucagonoma in humans
C. Clinical signs
1. Older dogs
2. Severe crusting of the footpads, elbows, commissures of the mouth
3. Systemically ill; associated with liver disease
D. Diagnosis
1. Signalment and clinical signs
2. Histopathology
3. Evidence of liver failure
E. Treatment
1. Typically unsuccessful; extremely guarded prognosis
2. Correct the liver disease if possible
3. Nutritional management

AUTOIMMUNE SKIN DISORDERS

I. These diseases are similar in that they are different manifestations of autoimmunity, or loss of tolerance for "self" tissues
II. Lesions are typically crusts covering erosions or ulcers
III. Common areas of the body affected include the nasal planum, the ear pinnae, and the footpads. Some diseases also have oral cavity or mucous membrane involvement
IV. Diagnosis is made via skin biopsy for histopathology with or without additional lab work in diseases with systemic signs
V. Treatment
A. Immunosuppressive doses of corticosteroids
B. Azathioprine: Dogs only
C. Chlorambucil: Typically used in cats
D. Other immunosuppressive agents, such as cyclosporine or gold salts
VI. Pemphigus complex. Mechanism of disease: IgG directed at particular adhesion molecules within the epidermis, resulting in acantholysis of keratinocytes. Lesions vary from pustules to superficial or deep erosions to ulcers
A. Pemphigus foliaceus
1. Most common of the autoimmune skin disorders
2. Epidermal involvement only
3. Planum, pinnae, footpads, and other body areas can be affected
4. Characterized by subcorneal to intraepidermal pustules: Superficial layers of the epidermis, resulting in crusts
5. Because this disease is usually pustular, it can mimic pyoderma
6. Pustule cytology = acantholytic cells and neutrophils
7. Antinuclar antibody (ANA) negative
B. Pemphigus vulgaris
1. Rare in dogs and cats
2. Oral cavity plus epidermal involvement
3. Serious, often fatal disease
4. Deep erosions down to the basal layer of the epidermis
5. Cytology = acantholytic cells and neutrophils
6. ANA negative
C. Pemphigus erythematosus
1. Considered a "benign" variation of pemphigus foliaceus as it affects the face only
2. This disease also has some similar histopathologic and clinical features of lupus
3. Lesions are pustules and crusts
4. ANA may be positive

V. Bullous diseases: Bullous pemphigoid
A. This is a bullous disease with separation of the epidermis from the dermis
B. Clinically identical to pemphigus vulgaris, a serious, often fatal, disease
C. Deep lesions that involve the basement membrane zone
D. Lesions are ulcers and crusts; acantholytic cells are not found on cytology or histopathology with bullous diseases
E. ANA negative

VI. Lupus
A. Mechanism of disease: Presence of antibodies against nuclear antigens
B. Diagnosis is made using the results of skin biopsy for histopathology as well as screening lab work with or without ANA testing
C. Discoid lupus erythematosus
1. Common autoimmune disorder, especially in dogs
2. No systemic signs; cutaneous lesions only
3. Lesions are crusts and erosions with hypopigmentation affecting the nasal planum and possibly the eyelids, footpads, or scrotum
4. ANA negative
5. Diagnosis
a. Histopathology
b. Must rule out systemic illness with screening lab work
6. Treatment
a. Doxycycline or niacinamide orally
b. Topical therapy
(1) Tacrolimus (Protopic)
(2) Water-resistant titanium based sunscreen (avoid ultraviolet light)
(3) Topical steroids have also been used successfully
D. Systemic lupus erythematosus
1. This is a systemic illness. Polyarthritis, pyrexia, renal disease and WBC abnormalities are some of the more common systemic signs
2. Cutaneous lesions are extremely variable
3. Oral lesions may be present
4. Diagnosis
a. Histopathology

b. Evidence of systemic disease from screening lab work
(1) Proteinuria with or without azotemia
(2) Hyperproteinemia
(3) Frequently pancytopenia
c. ANA positive

IMMUNE-MEDIATED DISORDERS

I. Uveodermatologic syndrome (Vogt-Koyanagi-Harada, or VKH)
A. Intense immune-mediated response targeting melanocytes
B. Melanocytes present in hair, skin, and retinal tissue
C. Melanocytes are eventually destroyed
D. Clinical signs
1. Young adult dogs
2. Nordic breeds typically
3. Acute onset of uveitis
4. Hypopigmentation of the skin, usually noted on the face
E. Diagnosis
1. Signalment and clinical signs
2. Skin biopsy for histopathology
3. Histopathology often performed on the ocular tissue if enucleation is performed
F. Treatment
1. Treat the uveitis
2. Skin lesions are cosmetic, and eventually all melanocytes will be destroyed

II. Dermatomyositis
A. Inherited disorder seen in Collies and Shetland sheepdogs
B. Inflammatory response targeting the hair follicles and muscles of mastication resulting in muscle atrophy and scarring
C. Clinical signs
1. Onset typically before 1 year of age
2. Alopecia, erythema, erosions to ulcers with crusts
3. Myopathy: Not present in all patients
D. Diagnosis
1. Breed and clinical signs
2. Histopathology, skin and muscle
E. Treatment
1. Pentoxifylline with or without corticosteroids
2. Recommend against breeding

III. Juvenile cellulitis
A. Commonly referred to as "puppy strangles"
B. Immune-mediated process seen in young dogs. The trigger is unknown; however, most animals have a concurrent staphylococcal infection
C. Clinical signs
1. Pustules, crusts, cellulitis usually affecting the head and neck
2. Regional lymphadenopathy
3. Pyrexia, lethargy, depression
D. Diagnosis
1. Signalment and clinical signs
2. Rule out other causes of folliculitis
E. Treatment
1. Systemic antibiotics for bacterial skin infection
2. Corticosteroid therapy also required

IV. Erythema multiforme and toxic epidermal necrolysis
A. Unknown mechanism. Thought to be caused by an antigen that could be a drug, toxin produced by a neoplasm, or related to vaccination
B. Clinical signs
1. Vesicular to ulcerative skin lesions
2. May be systemically ill
C. Diagnosis
1. History, clinical signs
2. Skin biopsy for histopathology
D. Treatment
1. Identify the underlying cause and avoid it
2. Supportive therapy
3. Immunosuppressive therapy may be required

V. Sebaceous adenitis
A. Immune-mediated destruction of the sebaceous glands
B. Eventual destruction of the sebaceous glands
C. Breed disposition: Standard poodle, Akita, Samoyed, vizsla
D. Clinical signs
1. Excessive scale with evidence of follicular casts and patchy alopecia
2. Secondary bacterial and yeast infections common
3. Typically nonpruritic
E. Diagnosis: Histopathology is diagnostic
F. Treatment
1. Antiseborrheic therapy
2. Topical treatments aimed at "replacing" the sebum

VI. Plasma cell pododermatitis
A. Thought to be immune mediated, but the exact mechanism is unknown
B. Soft, painless swelling of the footpads in cats
C. Affects multiple footpads and multiple feet
D. Diagnosis
1. Clinical signs
2. Histopathology
E. Treatment
1. Doxycycline orally
2. Corticosteroids
3. May spontaneously regress

NODULAR SKIN DISORDERS

I. The main differential diagnoses for these lesions include infectious causes, neoplasia, or sterile inflammatory causes

II. Diagnosis
A. Deep skin biopsy for histopathology; must include the subcutis for evaluation
B. Tissue culture to rule out infectious causes

III. Infectious causes
A. Bacterial infections
B. Fungal infections
C. Atypical mycobacterial infections

IV. Neoplasia
V. Sterile diseases
 A. Sterile granuloma
 B. Sterile nodular panniculitis
VI. Treatment depends entirely upon the diagnosis

OTITIS

I. Histologically the ear is an extension of the skin
II. Conditions that affect the skin will also affect the external ear canals
III. Cerumen: Waxy debris found in the ear canal produced by sebaceous and apocrine glands lining the canals. It functions to trap foreign material and can complicate treatment and resolution of otitis when produced in abnormal amounts
IV. Otitis externa
 A. Inflammation of the external ear canal
 B. Primary causes
 1. Parasites
 a. *Otodectes cyanotis* = ear mites
 b. *Otobius megnini* = spinous ear tick
 c. *Demodex* mites
 d. *Eutrombicula alfreddugesi* = chiggers
 e. *Sarcoptes scabiei*
 f. Poultry mites
 2. Allergic disorders
 a. Most common cause for chronic otic inflammation in dogs
 b. Atopy
 c. Adverse reaction to food (food allergy)
 d. Contact dermatitis or irritant contact dermatitis
 3. Foreign bodies
 4. Keratinization disorders
 a. Primary seborrhea
 b. Hypothyroidism
 5. Neoplasia of the ear canal
 6. Autoimmune disorders
 C. Predisposing causes
 1. Factors that alter the microenvironment
 2. Conformation
 a. Breeds with increased numbers of ceruminous glands (e.g., cocker spaniels)
 b. Breeds with stenotic ear canals (e.g., shar-pei, chow chow)
 c. Pendulous pinnae may restrict aeration of the canal
 3. Excessive moisture
 a. Frequent swimming
 b. Improper cleaning
 c. Obstruction of the ear canal
 D. Perpetuating factors
 1. Always secondary to a primary problem
 2. Yeast otitis: *Malassezia pachydermatis*
 3. Bacterial otitis: *Staphylococcus pseudintermedius*, *Pseudomonas aeruginosa* most common
 4. Otitis media
 5. Chronic pathologic changes: Hyperplasia, stenosis, and altered glandular secretions within the ear favoring microbial colonization and poor healing
 6. Treatment errors
 E. Diagnosis
 1. Physical examination
 2. Otic examination
 3. Otic cytology
 4. Culture and sensitivity when indicated
 F. Management
 1. Resolve primary factors if possible
 2. Reduce inflammation
 3. Treat any secondary infections present
 4. Identify and treat the underlying problem
V. Otitis media, interna
 A. Inflammation of the middle ear
 B. Anatomy of the middle ear includes the tympanic membrane, bullous cavity, auditory tube, and auditory ossicles
 C. Usually an extension of otitis externa through a damaged tympanic membrane
 D. May see extension via the auditory tube or hematogenous spread. Auditory tube extension more common in cats with upper respiratory infections
 E. Diagnosis
 1. Observation of abnormal tympanic membrane
 2. Radiographic or computed tomography scan changes in the bulla
 3. Pain upon opening the mouth
 4. Myringotomy and aspiration of fluid for cytology and culture and sensitivity
 5. Neurologic abnormalities: Facial nerve paralysis, Horner syndrome
 F. Treatment
 1. Long-term oral antibiotic therapy based on culture and sensitivity results
 2. Nonototoxic topical antibiotic
 3. Ear flushing under general anesthesia may be required to remove excessive cerumen and debris

Supplemental Reading

Campbell KL. *Small Animal Dermatology Secrets*. Philadelphia, 2004, Hanley & Belfus.
Medleau L, Hnilica KA. *Small Animal Dermatology: A Color Atlas and Therapeutic Guide*, 2nd ed. St Louis, 2006, Saunders.
Rhodes KH. *The 5-Minute Veterinary Consult Clinical Companion: Small Animal Dermatology.* Philadelphia, 2002, Lippincott Williams & Wilkins.
Scott DW, et al. *Muller and Kirk's Small Animal Dermatology*, 6th ed. Philadelphia, 2001, Saunders.

Emergency Medicine

14 CHAPTER

Patricia A. Schenck

FLUID THERAPY

I. Indications
 A. Resuscitation from shock
 B. Correction of dehydration, hypokalemia, and metabolic acidosis
 C. Correction of other electrolyte disturbances
 D. Parenteral nutrition
 E. Treatment of anemia and coagulopathies

II. Distribution of body water and electrolytes
 A. Water
 1. Total body water is about 50% to 70% of body weight in adults. Cats have slightly less body water; young animals and neonates have a higher percentage of body water
 2. Intracellular water is about 40% of body weight
 3. Extracellular water is about 20% of body weight
 4. Interstitial fluid is about 12% to 14% of body weight, and intravascular fluid is about 6 to 8% of body weight
 B. Electrolytes
 1. Sodium and chloride are high in extracellular fluid and low in intracellular fluid
 2. Potassium, magnesium, and phosphorus are low in extracellular fluid and high in intracellular fluid

III. Maintenance requirements
 A. Water intake should equal water loss in normal animals
 B. Insensible water loss is about 20 mL/kg/day
 C. Sensible losses are 20 to 40 mL/kg/day in normal animals consuming food
 D. A 0.45% sodium chloride solution makes a good maintenance solution but does not contain adequate potassium. Lactated Ringer's and 0.9% sodium chloride are not good maintenance solutions because they contain too much sodium and chloride

IV. Replacement needs (dehydration)
 A. Causes of dehydration
 1. Decreased water intake (decreased thirst and appetite centers in sick animals, decreased food intake)
 2. Increased water loss (e.g., polyuria, vomiting, diarrhea, salivation, burns)
 B. Type of dehydration
 1. Isotonic dehydration
 a. Normal serum sodium concentration in the presence of dehydration
 b. Occurs when there is a loss of water and electrolytes in proportion to that in serum.
 2. Hypertonic dehydration
 a. Elevated serum sodium concentration in the presence of dehydration
 b. Occurs when there is water loss in excess of electrolytes in serum
 3. Hypotonic dehydration
 a. Low serum sodium concentration in the presence of dehydration
 b. Loss of isotonic fluid with intake and absorption of hypotonic fluids with a net dilutional effect
 C. Detection of dehydration
 1. Dehydration is detectable when approximately 5% of body weight in water has been lost. An acute loss of more than 12% body weight in water is life-threatening
 2. History of decreased water intake or vomiting, polyuria, diarrhea, excessive panting or salivation may suggest dehydration
 3. Physical examination
 a. Findings associated with dehydration include depression, acute loss of body weight, sunken eyes, decreased skin turgor, dry mucous membranes, tachycardia, diminished capillary refill, and signs of shock
 b. Skin turgor
 (1) When skin is lifted a short distance, it should return quickly
 (2) As dehydration progresses, the time required for the skin to return to its normal position increases
 (3) Dehydration is as much as 5% to 10% before a loss of skin turgor can be detected
 D. Assessment of dehydration
 1. Packed cell volume (PCV) and total plasma protein both increase with dehydration
 2. Urine specific gravity should increase in a dehydrated animal if the kidneys are healthy
 3. Metabolic acidosis is common in dehydration
 E. Correction of dehydration
 1. Volume of fluid = % dehydration × weight (kg) = liters of fluid to be replaced
 2. Type of fluid is chosen based on electrolyte status and acid-base status

V. Types of fluids
 A. Crystalloid solutions redistribute quickly. Best for rehydration or replacement of fluid loss

1. Osmolality
 a. Hypotonic: Osmolality less than 300 mOsm/kg (0.45% saline)
 b. Hypertonic: Osmolality greater than 300 mOsm/kg (5% dextrose in 0.9% saline)
 c. Isotonic: Osmolality near 300 mOsm/kg (lactated Ringer's solution, Plasma-Lyte 148, Normosol-R, 0.9% saline)
2. Replacement fluids are formulated for specific electrolyte deficits
3. Maintenance fluids may differ greatly from serum, and becausee they usually contain glucose, their effect is hypotonic. The energy available from these fluids is insufficient to meet nutritional needs

B. Colloid solutions contain large macromolecules and attract water out of interstitial spaces. They are ideal for replacing intravascular volume but are not good for replacing extravascular fluid loss
1. Natural colloids are produced in the body and harvested for later use (blood transfusion components)
2. Synthetic colloids (such as hetastarch) are complex polysaccharide molecules
 a. Used in conjunction with crystalloid fluid therapy. They are used primarily in patients with hypoproteinemia and low oncotic pressure and in the treatment of shock
 b. Use with caution in those at risk for noncardiogenic pulmonary edema, in patients with congestive heart failure (CHF), and in those with renal origin oliguria or anuria

C. Fluids to keep on hand
1. The fluid of choice in the absence of laboratory data is an alkalinizing basic electrolyte solution (lactated Ringer's solution, Plasma-Lyte 148, Normosol-R)
2. If extra sodium or chloride is needed to maintain volume expansion or correct metabolic alkalosis, 0.9% saline is chosen
3. When treating patients with hypernatremia or a water deficit, choose a low-sodium fluid (0.45% saline in 2.5% dextrose, Plasma-Lyte 56, Normosol-M, or 5% dextrose in water)
4. Keep a synthetic colloid on hand to administer in conjunction with crystalloid fluids when rapid intravascular expansion is needed or if there is lowered oncotic pressure

VI. Supplementation of parenteral fluids

A. Potassium
1. Added to fluids if serum potassium concentration is less than 3.5 mEq/L. May still be indicated if potassium is between 3.5 and 4.5 mEq/L if ventricular arrhythmias are present
2. Add approximately 20 to 30 mEq/L of potassium to maintenance fluids if needed
3. The rate of infusion is most important. Do not exceed a rate of 0.5 mEq/kg/hr
4. Use potassium supplementation with caution as death can result due to hyperkalemia

B. Alkali
1. Add sodium bicarbonate if alkali replacement is needed quickly
2. Do not add sodium bicarbonate to fluids containing calcium
3. Do not use in patients with respiratory dysfunction

C. Magnesium
1. Indicated in patients with hypokalemia, diabetic ketoacidosis, and CHF
2. Magnesium sulfate or magnesium chloride is commonly used
3. Do not use in oliguric patients

D. Dextrose: Indicated in hypoglycemia owing to sepsis, insulinoma, overdose of insulin, and liver disease

E. Calcium
1. Use either calcium gluconate or calcium chloride
2. Do not use subcutaneously (SC)
3. Indicated in hypocalcemic seizures or tetany. Monitor heart rate; bradycardia is a sign of toxicity

F. Phosphorus
1. Only significant hypophosphatemia requires phosphorus supplementation (usually in diabetic ketoacidosis)
2. Avoid oversupplementation

VII. General guidelines for fluid selection

A. Serum sodium level as a guide
1. If sodium is normal (normonatremia), use fluids that are normal in sodium and osmolality (lactated Ringer's, Plasma-Lyte 148, Normosol-R, or 0.9% NaCl)
2. If serum sodium is elevated (hypernatremia), the fluids should contain more water than salt. Choose a hypotonic solution (5% dextrose in water, 0.45% NaCl in 2.5% dextrose)
3. If serum sodium is low (hyponatremia), fluids should contain more salt However, hypertonic fluids are usually not used unless hyponatremia is severe

B. Preservatives
1. Benzoic acid may be used as a preservative, and can be toxic
2. Signs of toxicity are neurologic
3. Do not use fluids containing preservatives in cats, puppies, or small dogs

VIII. Routes of administration for parenteral fluids

A. SC route
1. Do not use in shock, severe dehydration, hypothermia, or emergency replacement of fluids
2. Do not give 5% dextrose in water SC with severe dehydration
3. Choose a site on the trunk for administration

B. Intravenous (IV) route
1. Use for accurate delivery of large amounts of fluids
2. Use the jugular vein in cats and small dogs, or if serious disease is present
3. Cephalic, femoral, or lateral saphenous veins are also used
4. Use 20- to 22-gauge in cats and small dogs, and 14- to 20-gauge in medium to large dogs
5. Place catheter aseptically, and change every 72 hours. Monitor for fever, white blood cells (WBCs), and heart murmurs

C. Intraperitoneal route is used for transfusions in anemic puppies and kittens

IX. Rate of fluid infusion
 A. It is best to distribute fluids evenly throughout the day
 1. May not be possible if the IV line cannot be watched
 2. Can give the 24-hour load over 4 to 8 hours if necessary
 B. Infusion pumps provide an accurate method of delivering IV fluids
 C. "Ins and outs"
 1. Measure urine output in animals with severe oliguria or polyuria. Otherwise, fluid needs are overestimated in oliguria and underestimated in polyuria
 2. Body weight should remain static

X. Monitoring efficacy of fluid therapy
 A. Body weight: A gain or loss of 1 kg body weight represents an increase or decrease of 1000 mL of body water
 B. PCV and plasma protein should both decrease with successful rehydration
 C. Central venous pressure (CVP) should be monitored to prevent overloading of the heart and pulmonary edema. If CVP increases suddenly, the rate of fluid administration should be decreased
 D. Electrolyte and acid-base status: Determine electrolytes and acid base status every 12 to 24 hours

XI. Overhydration
 A. Clinical signs include an increase in body weight, increase in CVP, increased urination, gelatinous feel to SC tissue, pulmonary edema, vomiting, or diarrhea
 B. Discontinue all IV infusions, and give furosemide

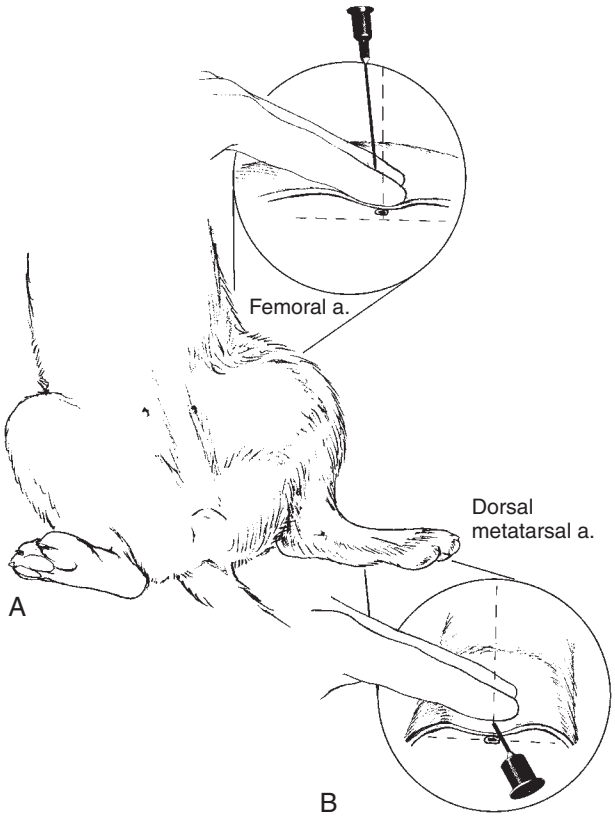


Figure 14-1 **A,** Femoral artery puncture. **B,** Dorsal metatarsal artery puncture. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

EMERGENCY TECHNIQUES

I. Arterial sampling for blood gas analysis
 A. Do not perform if a severe coagulopathy is present
 B. Use a heparinized syringe. The most common sites are the femoral artery in the inguinal region, and the dorsal metatarsal artery distal to the tarsus joint (Figure 14-1)
 C. After bleeding, place firm pressure over the site for 3 to 5 minutes

II. Nasogastric tube
 A. Do not place in patients with deforming facial trauma, in brachycephalic breeds with respiratory distress, if severe coagulopathy is present, or if there is severe vomiting
 B. Premeasure the catheter to the last rib. Place several drops of local anesthetic into the nostril and wait several minutes
 C. Place the tip of the catheter in the nostril, and gently push the catheter up on the nasal philtrum, advancing the tube in a ventral and medial direction into the ventral meatus (Figure 14-2)
 D. Suture the tube to the nostril, and use skin staples to attach the tube to the face
 E. Verify placement with radiographs

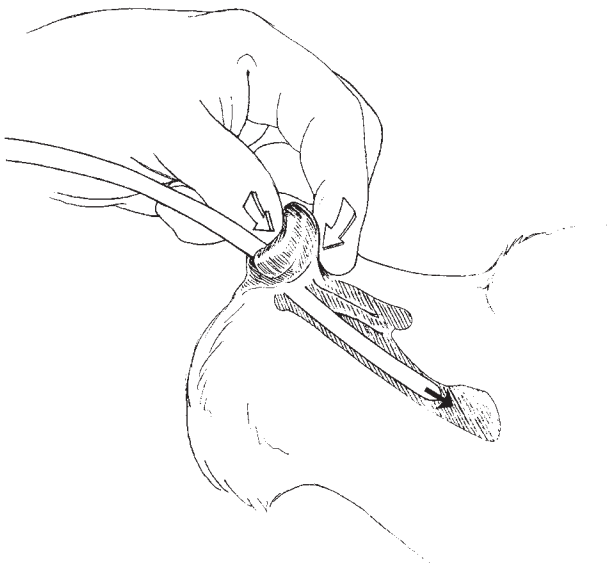


Figure 14-2 Positioning for placement of nasal catheter. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

III. Tracheostomy
 A. Severe coagulopathy is a contraindication
 B. Use rapid IV anesthesia; clip and prepare the skin
 C. Incise skin from larynx to the thoracic inlet. Bluntly force the tips of Mayo scissors through the tissue. Incise the sternohyoideus muscle to expose the trachea
 D. Either incise between two rings in the midcervical trachea or longitudinally cut through several rings. Insert tracheostomy tube (choose a tube that fits loosely). Suture the skin edges (Figures 14-3 and 14-4)
 E. Clean or replace as necessary

IV. Abdominocentesis
 A. Severe coagulopathy is a contraindication. Do not use a blind technique if there is a large abdominal mass or significant organomegaly
 B. It is best to have the patient standing or in sternal recumbency. Left lateral or dorsal recumbency can also be used

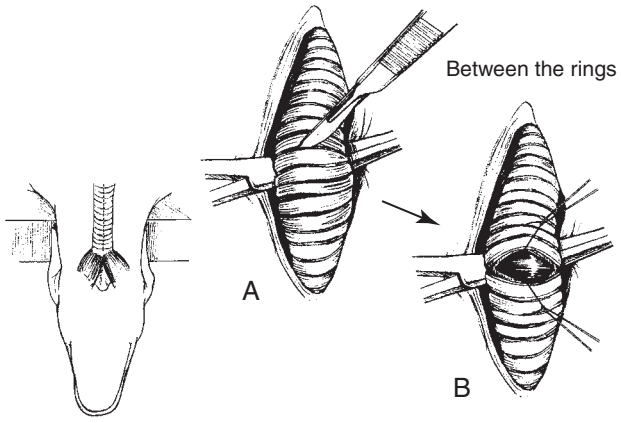


Figure 14-3 Between-the-rings tracheostomy with stay suture placement. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

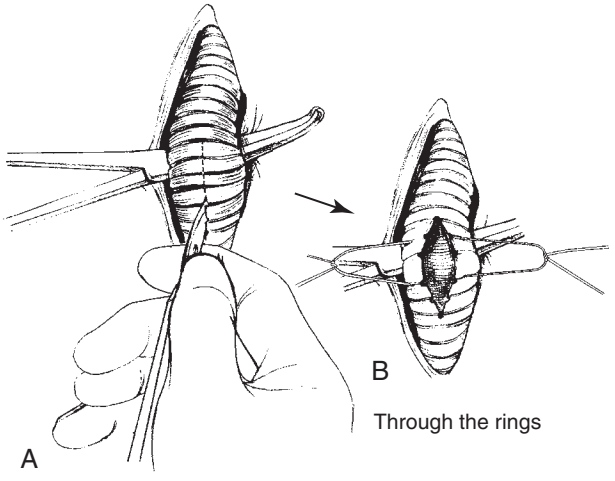


Figure 14-4 Through-the-rings tracheostomy with stay suture placement. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

 C. A good site for collection in standing patients is caudal to the spleen, slightly to the right of midline, with the needle directed toward the urinary bladder. If in left lateral recumbency, go caudal to the umbilicus, slightly to the right of midline, with the needle directed toward the urinary bladder
 D. Aspirate gently to avoid clogging of the needle with omentum

V. Thoracocentesis
 A Do not attempt in animals with chronic effusions (especially cats). These patients are at high risk for developing fibrosing pleuritis
 B. If there is fluid in the chest, the site should be ventral in the 3rd to 7th intercostal spaces about one third of the distance between the costochondral juction and sternum. If there is pneumothorax, the site should be dorsal in the 5th to 9th intercostal spaces about one third down from the dorsal chest wall
 C. Advance the sharp point, with slight negative pressure on the syringe, until a "pop" through the parietal pleura is felt. Advance catheter, remove needle or stylus, attach three-way stopcock, and drain
 D. Avoid laceration of the lung parenchyma or laceration of a coronary artery

SHOCK

I. Etiologies
 A. Lack of oxygen transport
 1. Hypovolemia
 2. Hypoxia
 B. Cardiovascular system abnormalities
 C. Sepsis

II. Clinical signs
 A. Depressed mentation
 B. Weak pulse indicating decreased cardiac output or peripheral vascular resistance
 C. Color of mucous membranes
 1. Pale: Reflects anemia or hypovolemia
 2. Gray or cyanotic: Reflects arterial hypoxemia or severe cardiovascular compromise
 3. Brick red: Common in septic shock
 D. Hypothermia with cold extremities
 E. Prolonged capillary refill time indicating hypovolemia and poor peripheral blood flow
 F. Elevated heart rate
 G. Increased respiratory rate
 H. Decreased urine output

III. Monitoring
 A. Blood volume is the most important parameter to optimize. Measure CVP using a manometer attached to a jugular catheter. Maintain plasma proteins
 B. Arterial pressure can be assessed via digital palpation
 C. Cardiac output
 1. Urine output is a good indicator
 2. Capillary refill time, body temperature, and mentation also reflect cardiac output
 D. Oxygen delivery is reflected in the color of mucous membranes, body temperature, respiratory rate, and temperature. Measure hematocrit frequently during fluid therapy

V. Treatment
 A. The goal is to optimize functions of the cardiovascular system
 B. Initial therapy
 1. Establish an airway and administer oxygen if needed
 2. Obtain history; perform physical examination
 3. Place a jugular catheter
 4. Obtain blood for complete blood cell count (CBC), hematocrit, total protein, electrolytes, creatinine, and glucose
 C. Blood volume
 1. Administer either 0.9% NaCl or lactated Ringer's solution to ensure plasma volume expansion. If the animal is not hydrated, 0.7% NaCl (hypertonic saline) can be used in combination with hetastarch
 2. Re-establish normal arterial pressure
 3. Give fresh or frozen plasma if hypoproteinemia is present. Synthetic colloids (such as hetastarch) can also be used
 4. Give fresh or stored blood if the hematocrit and total protein are very low
 D. Blood flow
 1. Evaluate cardiac function if CVP has increased but other signs of cardiac output are not normalized
 2. If the electrocardiogram is normal, administer a positive inotropic agent such as dobutamine or dopamine. Epinephrine can also improve contractility and increase cardiac output
 3. Correct any cardiac arrhythmias
 E. Blood pressure
 1. If the pulse is weak or not palpable, blood pressure needs to be increased immediately
 2. Epinephrine can be used if shock is severe
 3. Do not use an abdominal wrap to increase blood pressure
 4. Manage hemorrhage with aggressive fluid replacement
 F. Oxygen delivery
 1. If the hematocrit is below 20%, replace red blood cells
 2. Administer corticosteroids before transfusion to reduce transfusion reactions
 3. Administer oxygen supplementation
 4. With severe lung injury, assist ventilation
 G. Correct acid-base and electrolyte disturbances
 1. Perform a blood gas analysis to assess metabolic acidosis. Correct acidosis with sodium bicarbonate
 2. Hyperkalemia is common and usually corrects with fluid replacement therapy and improvement of metabolic state
 3. Hypokalemia occurs commonly after aggressive fluid therapy. Maintenance fluids should contain KCl
 H. Corticosteroid therapy should not be used in cases of septic shock. Corticosteroids (such as dexamethasone sodium phosphate or prednisolone sodium succinate) should be given early in the course of therapy
 I. Miscellaneous treatments
 1. Broad spectrum antibiotics are indicated especially in septic shock
 2. Maintenance fluids should contain 5% dextrose

CARDIOPULMONARY RESUSCITATION

I. Phase 1: Basic life support
 A. **A**irway: Establish an airway as soon as possible (endotracheal tube, tracheotomy, mouth to muzzle
 B. **B**reathing: Use a ventilator or exhaled air. Do not overinflate the lungs. Sedation or anesthesia may be necessary
 C. **C**irculation: Closed chest compression
 1. In dogs that weigh less than 5 kg, use the thumb and first two forefingers to compress the thorax from side to side. In larger dogs, use the heel of the hands. Provide 80 to 100 compressions/minute
 2. Ventilate once for every 15 chest compressions
 3. If a third person is available, use the palm of the hand to compress the abdomen against the spine for 5 to 10 seconds. Do this 2 to 3 times per minute.
II. Phase 2: Advanced life support
 A. **D**rug Therapy: Administer IV if possible
 1. Epinephrine to increase heart rate and blood pressure
 2. Lidocaine to treat cardiac arrhythmias. Do not give to patients with third-degree atrioventricular (AV) block
 3. Sotalol is used for long-term therapy of arrhythmias
 4. Sodium bicarbonate treats metabolic acidosis. Not needed until after 10 to 15 minutes of arrest
 5. Anticholinergics (atropine) treat bradyarrhythmias. Do not give unless indicated
 6. Calcium chloride can increase myocardial contraction and cardiac output. Do not use during the initial phase of treatment
 B. Parenteral fluids are mandatory (see previous section on fluid therapy). Use whole blood if hemorrhage is severe
 C. **E**lectrocardiography (see section on cardiology)
 D. Treat bradycardia. If hypoxemic, large doses of epinephrine may be needed. Isoproterenol may be effective in some cases
 E. Treatment of ventricular **f**ibrillation. The only consistent method for treatment is with electrical defibrillation
 F. Open-chest cardiac massage should be considered if 5 minutes of closed chest compression and epinephrine are ineffective
III. Phase 3: Prolonged life support. Adequate oxygenation is critical
 A. **G**auging, **H**ypnogenesis (sedation, pain control), **I**ntensive care
 B. Drug therapy
 1. Catecholamines (dopamine, dobutamine) to increase cardiac output and peripheral perfusion
 2. Diuretics (furosemide) to treat pulmonary edema. Mannitol can be used if the cardiac arrest was longer than 3 minutes

3. Glucocorticoids (dexamethasone or prenisolone sodium succinate) prevent histamine release, stabilize membranes, and cause vasodilation
4. Calcium entry blockers (diltiazem) prevent reperfusion injury
5. Sedation. Diazepam is a good alternative to pentobarbital
6. Antibiotics

IV. Prognosis is good if there is rapid recovery of corneal reflexes, swallowing, and spontaneous breathing

BLOOD TRANSFUSION

I. Whole blood is indicated when there is a rapid decrease in PCV
II. Crossmatching
 A. Perform before transfusion
 B. Collect both RBCs and serum from both the donor and the patient
 C. Measure compatibility between donor and patient at three temperatures
 D. Incompatibility is agglutination or hemolysis
 1. Major incompatibility: Mix 100 μL donor cells + 100 μL patient serum
 2. Minor incompatibility: Mix 100 μL patient cells + 100 μL donor serum
 E. Donors can be used if there is mild agglutination in the minor cross-match in an emergency
 F. In dogs, it is best to use animals that do not have dog erythrocyte antigen DEA-1 and DEA-7
 G. Most cats have type A blood but should still be crossmatched due to fatal transfusion reactions

HEATSTROKE

I. Cellular damage results from a marked increase in body temperature with loss of temperature control. In heatstroke, heat production overwhelms normal heat dissipation mechanisms
II. Heatstroke usually occurs when the ambient temperature is high. High humidity, lack of water, poor ventilation, obesity, airway obstruction, heart disease, central nervous system disease, hyperthyroidism, seizures, and lack of conditioning can contribute to the development of heatstroke
III. Clinical signs
 A. Early clinical signs include panting, hypersalivation, tachycardia, short capillary refill time, increased blood pressure, bounding pulse, excitation, hyperactivity, elevation of body temperature
 B. As heatstroke progresses, signs of shock are more pronounced. Rectal temperature may be elevated but can be normal to low. Tachycardia, tachypnea, and hyperventilation are common. Dehydration is common, and hematemesis and melena signify injury to the gastrointestinal tract. Mentation is altered, and the pupils are dilated. Disseminated intravascular coagulation (DIC) is common, with petechiation and hemorrhage. Azotemia from renal failure is common. Seizures or coma may occur
IV. Treatment
 A. Early treatment is necessary to reduce mortality
 B. The core temperature needs to be lowered early. Cooling should be started during transport to the hospital
 1. Use cool water to wet the patient, and provide air movement to enhance evaporation
 2. Do not use cold water or ice water because to do so will result in vasoconstriction and loss of heat dissipation. Shivering can also result, which generates heat
 C. On arrival to the hospital, if the body temperature is below 104° F, cooling measures should be stopped to prevent the development of hypothermia
 D. Fluid therapy may not be necessary in early cases of heatstroke, but may need to be aggressive in severe cases. A combination of crystalloid and colloid fluids is recommended
 E. If DIC is present, the administration of fresh or frozen plasma is indicated
 F. Broad-spectrum antibiotics are recommended

ANAPHYLAXIS

I. Anaphylaxis is a life-threatening allergic reaction (type I hypersensitivity)
II. There is an interaction of antigen and immunoglobulin E (IgE) antibody on the surface of mast cells, which causes the release of histamine
III. Triggers include insect and reptile bites, medications, anesthetics, and foods
IV. Clinical signs include hypotension, bronchospasm, pruritus, erythema, pharyngeal and laryngeal edema, vomiting, and arrhythmias
 A. In dogs, the liver is the shock organ. Clinical signs result from hepatic congestion and portal hypertension
 B. In cats, the lungs are the shock organ. Respiratory distress is usually the first sign
V. Diagnosis is based on history, exposure, and clinical signs
VI. Treatment
 A. Establish an airway
 B. Maintain vascular access, and start fluid therapy for hypovolemic shock
 C. Administer epinephrine immediately
 D. Can also administer glucocorticoids, aminophylline, antihistamines, atropine, and pressors (dopamine)
VII. Prognosis is good if treatment is instituted early
VIII. Anaphylaxis is prevented by avoiding exposure to known triggers in the future

Supplemental Reading

Bateman S, Chew DJ. Fluid therapy for dogs and cats. In Birchard SJ, Sherding RF, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 82-99.

Bateman SW, Buffington CA, Holloway C. Emergency and critical care techniques and nutrition. In Birchard SJ, Sherding RF, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 29-50.

Day TK, Bateman S. Shock syndromes. In DiBartola SP, ed. *Fluid Therapy in Small Animal Practice.* St Louis, 2006, Saunders, pp. 540-566.

DiBartola SP, Bateman S. Introduction to fluid therapy. In DiBartola SP, ed. *Fluid Therapy in Small Animal Practice.* St Louis, 2006, Saunders, pp. 325-343.

Gfeller R. Heatstroke. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine.* St Louis, 2005, Saunders, pp. 437-440.

Hohenhaus AE. Blood transfusions, component therapy, and oxygen-carrying solutions. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine*. St Louis, 2005, Saunders, pp. 464-468.

Muir WW III. Cardiopulmonary cerebral resuscitation. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1609-1621.

Otto CM. Shock. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine*. St Louis, 2005, Saunders, pp. 455-457.

Raskin RE. Erythrocytes, leukocytes, and platelets. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 231-255.

Schertel ER. Shock. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1603-1608.

Waddell LS. Systemic Anaphylaxis. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine*. St Louis, 2005, Saunders, pp. 458-460.

Endocrine Disorders

15 CHAPTER

Patricia A. Schenck

DISORDERS OF THYROID METABOLISM

I. Normal thyroid function
 A. Hypothalamus secretes thyroid-releasing hormone (TRH), which stimulates the release of thyroid-stimulating hormone (TSH) from the pituitary gland. TSH stimulates the release of thyroid hormones from the thyroid glands. Released thyroid hormones exert negative feedback on the hypothalamus and pituitary glands to decrease the production of TSH
 B. Hormones produced by the thyroid
 1. Total T_4 (thyroxine, tetra-iodothyronine) includes free and protein-bound
 2. Total T_3 (tri-iodothyronine) includes free and protein-bound
 3. Free T_4 (FT_4)
 4. Free T_3 (FT_3) (the active thyroid hormone)

II. Tests for thyroid function
 A. Total T_4
 1. Measurement readily available
 2. May be falsely normal in hypothyroid dogs that have T_4 autoantibodies (T_4AA)
 3. 5% to 10% of hyperthyroid cats have normal T_4 concentrations
 B. Total T_3. False results occur in 20% of hypothyroid dogs because of the presence of T_3 autoantibodies (T_3AA).
 C. Free T_4
 1. Different methods available for measurement
 2. Free T_4 by equilibrium dialysis (FT_4d) is the "gold standard" measurement
 a. Less affected by illness or medication than are T_4 or other methods of FT_4 measurement
 b. Free from T_4AA interference
 c. More consistently increased in hyperthyroid cats with other concurrent illnesses
 d. Delayed or inappropriate shipping can cause increased values
 D. Free T_3. Not much diagnostic utility as a single test. False results occur in 20% of hypothyroid dogs because of the presence of T_3AA
 E. TSH
 1. Poor accuracy on its own but good accuracy in combination with thyroid hormone measurement
 2. Elevated in most cases of hypothyroidism but may also be elevated during recovery from illness or with administration of sulfa-containing antibiotics
 F. Thyroglobulin autoantibodies (TgAA) (dogs only)
 1. Marker for lymphocytic thyroiditis
 2. Can be detected before the development of hypothyroidism
 3. Detects active inflammation
 4. Provides no information concerning thyroid function
 G. T_3AA, T_4AA (dogs only)
 1. Present in some (but not all) dogs that have lymphocytic thyroiditis
 2. T_3AA interfere with measurement of T_3 and FT_3
 3. T_4AA interfere with measurement of T_4 and FT_4 (some methods) but do not interfere with FT_4d
 H. T_3 suppression test
 1. Used in the diagnosis of hyperthyroid cats
 2. A "pre" sample is taken for measurement of T_4, T_3, FT_4, and FT_3. T_3 supplement is given (25 ug) every 8 hours for six or seven treatments. A "post" sample is collected 2 to 4 hours after the last treatment
 3. In a normal animal, the administration of T_3 supplement should result in increases in T_3 and FT_3 concentrations in the "post" sample compared with the "pre" sample. This elevation of T_3 and FT_3 should cause suppression of T_4 and FT_4 production
 4. In hyperthyroid cats, T_3 and FT_3 concentrations increase in the post sample, but there is either no or poor suppression of T_4 and FT_4, indicating a loss of negative feedback

III. Hypothyroidism in dogs
 A. Hypothyroidism is the most common endocrine disease in dogs, with an estimated prevalence of approximately 0.5%. Most common in middle-aged purebred dogs. Can occur in any breed, but golden retrievers and Doberman pinschers have the highest incidence
 B. Pathogenesis
 1. Primary hypothyroidism (thyroid defect). In primary hypothyroidism, thyroid hormone synthesis is impaired, and concentrations of thyroid hormones decrease in serum. TSH increases in an attempt to stimulate thyroid hormone production
 a. Acquired (most common)
 (1) Lymphocytic thyroiditis (about 50% of cases)
 (2) Idiopathic thyroid follicular atrophy
 b. Congenital (dyshormonogenesis)

2. Secondary hypothyroidism (nonthyroid gland defect)
 a. Acquired (pituitary masses)
 b. Congenital (dwarfism, receptor defects, dyshormonogenesis)

C. Lymphocytic thyroiditis
1. Thyroglobulin autoantibody is a marker for lymphocytic thyroiditis. Some dogs also have autoantibodies to T_3 or T_4
2. Present in about 4% of healthy dogs
3. Hereditary
4. Breed predilection: English setter, dalmatian, basenji, Rhodesian ridgeback, Old English sheepdog, boxer, others
5. Stages of lymphocytic thyroiditis
 a. Subclinical thyroiditis
 (1) TgAA present
 (2) Thyroid hormone and TSH concentrations normal
 (3) Focal inflammatory infiltrates of lymphocytes
 (4) No clinical signs relating to hypothyroidism
 (5) Treatment with T_4 not warranted
 b. Subclinical hypothyroidism (partial thyroid failure)
 (1) TgAA present
 (2) Elevated TSH concentration
 (3) Thyroid hormone concentrations normal or borderline low
 (4) Extensive lymphocytic inflammatory infiltrates with follicular cell hypertrophy
 c. Clinical hypothyroidism
 (1) TgAA present
 (2) Low thyroid hormone concentrations, elevated TSH concentration
 (3) Extensive diffuse lymphocytic inflammatory infiltrates
 (4) Functional thyroid follicles rare

D. Clinical signs
1. Weight gain or obesity
2. Lethargy, weakness
3. Cold intolerance, heat seeking
4. Skin disorders occur in 85% of patients with hypothyroidism. Skin disorders include poor coat quality, alopecia, hypopigmentation, secondary pyoderma and pruritus, otitis
5. "Tragic" facial expression
6. Myxedema
7. Cardiac abnormalities including bradycardia, decreased contractility, and increased risk for atherosclerosis resulting from lipid metabolism abnormalities
8. Neurologic signs including generalized weakness, forelimb lameness, laryngeal paralysis, megaesophagus, vestibular disease (circling, head tilt, incoordination)
9. Ocular abnormalities including eyelid edema, corneal lipid deposits, keratoconjunctivitis sicca

E. Diagnosis
1. Clinical pathology findings include chronic fasting hyperlipidemia, hypercholesterolemia, hypertriglyceridemia, nonregenerative anemia in about 35%, nonspecific findings
2. Diagnosis should not be based on clinical signs alone
3. Primary hypothyroidism is diagnosed based on finding low concentrations of thyroid hormones with an elevation of TSH
4. Hypothyroidism should not be diagnosed based on a single low T_4 concentration

F. Other causes of low thyroid hormone concentrations
1. Metabolic response to nonthyroidal illness
 a. Often termed "sick euthyroid"
 b. FT_4 by equilibrium dialysis is often normal but may be low
2. Medications such as phenobarbital, glucocorticoids, sulfonamides
3. Sighthound breeds (such as greyhounds, salukis, others) may normally have lower concentrations of thyroid hormones than other breeds

G. Treatment
1. Supplemental T_4: 0.01 mg/lb once to twice daily
2. Fatty foods improve absorption of T_4
3. Peak absorption of supplement typically occurs about 3 to 4 hours after ingestion of supplement
4. Monitor thyroid hormone levels 3 to 4 weeks after starting supplement
5. Signs of hyperthyroidism such as anxiousness, panting, and hyperactivity may occur if the T_4 supplement dose is excessive
6. If thyroid supplement has been started before a definitive diagnosis of hypothyroidism, all supplements must be stopped for 4 to 6 weeks before testing thyroid function to determine whether hypothyroidism is actually present

IV. Hypothyroidism in cats
A. Naturally occurring is rare
B. Clinical signs include dwarfism, stunted growth, apathy, lethargy, constipation, thickened skin, seborrhea
C. Thyroid hormone concentrations are low, and TSH is elevated
D. Treatment with T_4: 0.01 to 0.02 mg/kg/day

V. Hyperthyroidism in cats
A. The average age for hyperthyroid cats is 12 to 13 years. Less than 5% of cases are in cats younger than 10 years
B. Hyperthyroidism is usually due to benign adenomatous hyperplasia. Thyroid carcinoma is rare
C. Clinical signs include weight loss, palpable goiter, polyphagia, polyuria, polydipsia, tachycardia, hyperactivity, diarrhea, cardiac abnormalities
D. Clinical pathology findings
1. Increased alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), phosphorus
2. Azotemia in 25%
3. Mild hyperglycemia
4. Stress leukogram, mature neutrophilia

E. Diagnosis
1. Significantly elevated thyroid hormones in many cases of hyperthyroidism

2. Occult hyperthyroidism
 a. Thyroid hormones may be normal or only slightly increased
 b. May need to perform a T_3 suppression test to demonstrate loss of negative feedback
 c. Day-to-day fluctuation in thyroid hormone production may result in normal thyroid hormone concentrations
 d. Concurrent nonthyroidal illness with hyperthyroidism may suppress hormone concentrations into normal range

F. Treatment
 1. Surgical thyroidectomy
 2. Radioactive iodine therapy
 3. Chronic methimazole therapy 5 mg twice or three times daily

G. Complications of therapy
 1. Transient or permanent hypoparathyroidism post surgery
 2. Hyperthyroidism may recur
 3. Reduced glomerular filtration rate (GFR)
 4. Renal failure in subclinical or compensated renal failure cases

VI. Hyperthyroidism in dogs
 A. Most thyroid tumors are carcinomas and are invasive
 B. Hyperthyroidism occurs in about 10% to 20% of thyroid carcinomas. Most thyroid tumors are nonfunctional and do not cause hyperthyroidism
 C. Clinical signs include visible neck mass, coughing, dyspnea, dysphagia, dysphonia, weight loss, hyperactivity
 D. Treatment
 1. Surgery and chemotherapy
 2. Treatment with oral thyroxine is recommended post surgery to suppress TSH and to prevent stimulation of potentially precancerous cells

DISORDERS OF ADRENAL FUNCTION

I. Normal adrenal function
 A. Adrenal cortex has three zones
 1. Zona glomerulosa secretes primarily mineralocorticoids
 2. Zona fasciculata secretes primarily glucocorticosteroids
 3. Zona reticularis secretes primarily sex hormones
 B. Pituitary gland normally secretes endogenous adrenocorticotrophic hormone (eACTH), which acts on the adrenal cortex to cause release of primarily cortisol. As cortisol increases, negative feedback mechanisms cause a decrease in production of eACTH

II. Tests for adrenal function
 A. Tests to help support a diagnosis of hyperadrenocorticism (HAC)
 1. Low-dose dexamethasone suppression test (LDDST)
 a. Blood sample collected before administration of dexamethasone
 b. Dexamethasone given intramuscularly at 0.01 mg/kg
 c. Post-samples taken 3 to 6 hours post and 8 hours post dexamethasone
 d. Measure cortisol concentration in samples
 e. Post dexamethasone cortisol concentration greater than 30 to 40 nmol/L suggests HAC
 f. Suppression of cortisol concentration greater than 50% of baseline (but still greater than 30 to 40 nmol/L) at 3 to 6 hours post or 8 hours post dexamethasone suggests pituitary-dependent hyperadrenocorticism (PDH)
 g. Suppression of cortisol concentration less than 50% of baseline (but still greater than 30-40 nmol/L) could indicate either PDH or an adrenal tumor (not diagnostic for adrenal tumor)
 h. If the LDDST is normal, HAC is unlikely
 i. False-positive results are seen especially when other illnesses such as diabetes mellitus (DM) are present
 j. Test not appropriate if there is a history of exogenous steroid use
 2. ACTH response test
 a. Test of choice if suspect iatrogenic HAC or hypoadrenocorticism, or when monitoring HAC therapy
 b. Measures adrenocortical reserve
 c. Baseline blood sample taken before administration of ACTH
 d. Depending on the type of ACTH used, the post sample is taken 1 or 2 hours after ACTH
 e. Cortisol is measured in both samples
 f. Post ACTH cortisol concentration greater than 550 to 600 nmol/L suggests HAC
 g. False-positive and false-negative results occur
 h. Disadvantage is that this test offers no insight as to the origin of HAC
 3. Urinary cortisol-to-creatinine ratio (UCCR)
 a. Have owners collect morning urine at home (nonstressed environment)
 b. If UCCR results are normal, HAC is very unlikely
 c. Convenient, inexpensive test with little stress on patient
 d. May be elevated in response to stress or other illness
 e. Elevation of UCCR is not diagnostic for HAC
 4. Corticosteroid-induced ALP (ciALP)
 a. If not elevated, HAC is very unlikely
 b. May be elevated in response to stress, glucocorticoid administration, or other illness
 c. Elevation of ciALP is not diagnostic for HAC
 B. Tests for differentiating the origin of HAC
 1. Dexamethasone suppression
 a. Low- or high-dose (0.1 mg/kg) dexamethasone suppression
 b. Greater than 50% suppression of cortisol from baseline sample suggests PDH

c. Less than 50% suppression of cortisol from baseline sample could indicate either PDH or adrenal tumor
d. High-dose dexamethasone suppression test should not be used for the diagnosis of HAC as some pituitary tumors will remain responsive to a high dose of dexamethasone and show normal suppression

2. Endogenous ACTH measurement
a. Concentration is very low with adrenal tumors because of negative feedback of excess cortisol on pituitary production of endogenous ACTH
b. Concentration of endogenous ACTH may be slightly subnormal, normal, or elevated in cases of PDH
c. Sample handling is critical since endogenous ACTH is very labile

3. Abdominal ultrasound
a. With an adrenal tumor, one adrenal gland may be enlarged and irregular in contour
b. With PDH, both adrenals are enlarged to a similar degree

III. HAC: Canine
A. Pathogenesis
1. PDH is caused by a pituitary microadenoma, macroadenoma, or adenocarcinoma
2. Adrenal-dependent HAC is caused by an adrenal adenoma or adenocarcinoma
3. Iatrogenic HAC is due to chronic exogenous steroid administration
a. Chronic steroid use causes clinical signs of HAC with suppression of cortisol production by the adrenal glands
b. Ear and eye medications containing steroids are readily absorbed and can cause iatrogenic HAC
c. The ACTH response test is the test of choice if iatrogenic HAC is suspected. Resting cortisol concentration is typically low with subnormal stimulation of cortisol with the administration of ACTH
d. Treatment is to remove the source of the exogenous steroids
e. Suppression of adrenal cortisol production from exogenous steroid administration may last 4 weeks or longer, depending on type of steroid used, the route of administration, and the duration of therapy

B. Signalment
1. Middle-aged to older dogs
a. PDH, approximately 7 to 9 years old (range, 2 to 16 years)
b. Adrenal tumor, approximately 11 to 12 years old (range, 6 to 16 years)

2. Sex predilection
a. No difference in PDH
b. More females than males are affected with adrenal tumors

3. Breed predilection
a. Any breed may be affected
b. PDH: Poodles, dachshunds, and small terriers (Yorkshire terrier, Parson Russell terrier, Staffordshire bull terrier) at increased risk
c. Adrenal tumor is more frequent in large breeds (weighing more than 20 kg)

C. Clinical signs
1. Polyuria or polydipsia
2. Polyphagia
3. Abdominal distension (pot-bellied appearance)
4. Muscle wasting and weakness
5. Lethargy, poor exercise tolerance
6. Skin thinning, decreased elasticity of skin, calcinosis cutis, hyperpigmentation
7. Symmetrical alopecia
8. Persistent anestrus or testicular atrophy

D. Clinical pathology findings
1. Findings are nonspecific
2. Stress leukogram: Mature neutrophilia, lymphopenia, eosinopenia, monocytosis
3. Hyperglycemia with or without glucosuria
4. Hypercholesterolemia, hypertriglyceridemia
5. Increased corticosteroid-induced ALP (ciALP), increased ALT, increased bile acid concentrations
6. Decreased thyroid hormone concentrations (with no elevation of TSH)
7. Decreased urine specific gravity (USG), increased incidence of urinary tract infections

E. Radiography findings
1. Nonspecific findings
2. Hepatomegaly, increased abdominal fat
3. Distended urinary bladder, cystic calculi
4. Soft tissue calcification

F. Diagnosis
1. Diagnosis is based on a combination of clinical signs and appropriate adrenal function test findings. The test of choice for diagnosis of naturally occurring HAC is the low-dose dexamethasone suppression test
2. False-positive and false-negative results occur with any adrenal function test
3. Stress of other concurrent illness often causes false-positive results (especially DM)
4. Borderline or positive test results in the absence of clinical signs is probably not HAC
5. An elevated resting cortisol concentration or elevated ALP concentration is not specific for HAC
6. Once a diagnosis of HAC has been made, further testing should be performed to determine the cause of the HAC

G. Treatment
1. Iatrogenic HAC: remove source of exogenous steroids
2. Adrenal tumor
a. Surgery is the treatment of choice, but it may be difficult because adrenal tumors are very vascular

b. Medical therapy
(1) Mitotane is used at higher doses than in PDH, with longer periods of induction
(2) Frequent monitoring (with ACTH response test) necessary
(3) Median survival time is 11 months
3. PDH
a. Surgery to remove the pituitary mass has very limited availability
b. Medical therapy
(1) Mitotane
(a) Causes destruction of the adrenal cortex
(b) Induction phase (25 to 50 mg/kg daily) followed by the maintenance phase (25 to 50 mg/kg once to twice weekly)
(c) Monitor with ACTH response test
(d) Oversuppression of cortisol production can occur, resulting in hypoadrenocorticism
(2) Trilostane
(a) Inhibits glucocorticoid, mineralocorticoid, and adrenal androgen production
(b) Daily medication
(c) Monitor with ACTH response test
(3) L-Deprenyl (selegiline hydrochloride)
(a) Long-term results are disappointing
(b) No severe adverse side effects
(c) Use clinical signs to monitor effectiveness
(4) Ketoconazole
(a) Suppresses steroidogenesis
(b) Monitor using ACTH response test

H. Atypical HAC (dogs)
1. Clinical signs of HAC are present, but dogs have normal cortisol values after adrenal function testing
2. Perform an ACTH response test, and measure intermediates in the cortisol pathway and sex steroids (progesterone, 11-deoxycorticosterone, 17-hydroxyprogesterone, androstenedione, dehydroepiandrosterone, testosterone, estradiol)
3. Abnormal elevations of intermediates or sex steroids in response to ACTH administration may suggest an adrenal tumor
a. Elevated 17-hydroxyprogesterone can occur with either pituitary or adrenal tumors
b. Elevated 17-hydroxyprogesterone can also occur with nonadrenal illness
4. If an adrenal tumor is present, adrenalectomy is the treatment of choice. Patients may also be treated with mitotane or trilostane

IV. HAC: Feline
A. Signalment
1. Uncommon in the cat; disease of middle-aged to older cats
2. Most cases are PDH
3. Most cats have concurrent DM

B. Clinical signs
1. Polyuria or polydipsia (usually secondary to DM)
2. Pot-bellied appearance
3. Polyphagia
4. Muscle wasting
5. Hair loss, thin skin, fragile skin
6. Lethargy, obesity, weight gain

C. Diagnosis
1. Clinical pathology
a. Hyperglycemia, glycosuria
b. Lymphopenia, eosinopenia, monocytosis
c. Hypercholesterolemia, increased ALT, increased ALP
2. Adrenal function tests
a. ACTH response test
b. Dexamethasone suppression test

D. Treatment
1. Adrenalectomy is the most successful method of treatment
a. Unilateral if adrenal tumor
b. Bilateral if PDH. Will require mineralocorticoid and glucocorticoid supplementation
c. May have increased risk of infection and delayed wound healing
2. Hypophysectomy for PDH (not readily available)
3. Medical therapy has been disappointing

V. Hypoadrenocorticism
A. Pathogenesis
1. Primary hypoadrenocorticism with deficiency of both glucocorticoid and mineralocorticoid production
a. Deficiency of glucocorticoid and mineralocorticoid
b. Idiopathic adrenocortical atrophy is most common due to immune-mediated destruction
c. Mitotane-induced adrenocortical necrosis
d. Bilateral adrenalectomy
e. Other causes such as hemorrhage, infarction, neoplasia, granulomas of adrenal glands
2. Secondary hypoadrenocorticism
a. Deficiency of eACTH production or release
b. Mineralocorticoid production is normal
c. Caused by tumors of pituitary or hypothalamus or prolonged suppression of ACTH by drug therapy

B. Signalment
1. Very rare in cats
2. Age: Young to middle-aged dogs (median, 4 years old; range, 3 months to 14 years)
3. Gender: Approximately 70% of cases are female
4. Breed: Any breed can be affected; however, incidence is greater in the Great Dane, Portuguese water dog, rottweiler, standard poodle, West Highland white terrier, soft-coated wheaten terrier, Great Pyrenees, bearded collie, Chinese crested

C. Clinical signs
1. Acute (life-threatening)
a. Hypovolemic shock
b. Collapse

c. Weak pulse, bradycardia (Figure 15-1)
d. Hypothermia
e. Abdominal pain, vomiting, diarrhea

2. Chronic
a. Vague, nonspecific signs exacerbated by stress
b. Waxing and waning course
c. Episodic weakness and collapse
d. Anorexia, weight loss, failure to gain weight
e. Lethargy, depression
f. Vomiting, diarrhea, melena, abdominal pain
g. Polyuria, polydipsia

D. Diagnosis
1. Clinical pathology
a. Lymphocytosis, eosinophilia, neutropenia
b. Normocytic, normochromic, nonregenerative anemia
c. Azotemia
d. Hyponatremia, hyperkalemia (Na:K less than 23:1)
e. Hypochloremia, hypoglycemia, hypercalcemia

2. Adrenal function tests
a. ACTH response test is the test of choice
b. Can measure both cortisol and aldosterone in pre- and post-samples
c. Both cortisol and aldosterone concentrations will be low in the baseline sample with little or no response to ACTH stimulation in primary hypoadrenocorticism
d. Cortisol concentration will be low in baseline with little or no response to ACTH stimulation, but aldosterone concentration will be normal in secondary hypoadrenocorticism (or iatrogenic HAC)

E. Treatment
1. Acute
a. Try to obtain diagnostic samples before treatment
b. Resuscitate intravascular volume
c. Provide glucocorticoids. Use dexamethasone if diagnostic samples cannot be obtained before treatment
d. Correct hyperkalemia
e. Treat life-threatening cardiac arrhythmias

2. Chronic
a. Mineralocorticoids
(1) Fludrocortisone once daily
(2) Desoxycorticosterone every 25 days
b. Glucocorticoids
c. Monitor effectiveness of therapy by evaluation of clinical signs and electrolytes

VI. Hyperaldosteronism
A. Pathogenesis
1. Aldosterone is produced by the zona glomerulosa
2. Influenced by renin-angiotensin system (RAS) and plasma potassium concentration
3. Primary hyperaldosteronism (adrenal tumor)
a. Increased production of aldosterone in the presence of low plasma renin concentration
b. Leads to hypernatremia, water retention, hypokalemia, and suppression of RAS
4. Secondary hyperaldosteronism
a. Hyperaldosteronism caused by continued stimulation of RAS

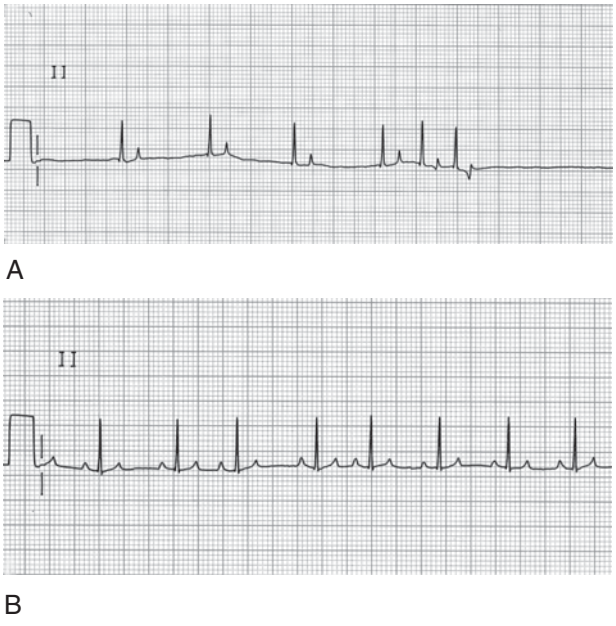


Figure 15-1 Electrocardiograms from a 4-year-old bearded collie dog with primary hypoadrenocorticism taken **(A)** before and **(B)** after supplementation with glucocorticoids and mineralocorticoids. Paper speed is 25 mm/sec and sensitivity is 1 cm = 1 mV. **A,** The P waves are absent, the T waves are peaked, and there is profound bradycardia. The serum sodium concentration was 138 mEq/L and the serum potassium 9.5 mEq/L. **B,** Electrocardiogram after treatment showing sinus arrhythmia. The serum sodium concentration was 142 mEq/L and the serum potassium 5.4 mEq/L. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medic*ine, 6th ed. St. Louis, 2005, WB Saunders.)

b. Considered in any patient with cardiac failure, renal disease, or hepatocellular disease

B. Signalment
1. Primary hyperaldosteronism is rare, but it is more common in cats
2. Typically occurs in older animals

C. Clinical signs
1. Related to decreased potassium
2. Weakness, lethargy, depression, polyuria or polydipsia, ventroflexion of the neck
3. Reluctance to move, poor muscle tone, apparent muscle pain
4. Systemic hypertension resulting from sodium and fluid retention

D. Diagnosis
1. Clinical pathology
a. Hypokalemia; serum potassium often below 3.0 mmol/L
b. Elevation of creatine kinase usually
c. Blood urea nitrogen (BUN) typically normal
2. Adrenal function testing
a. Perform ACTH response test (same procedure as for HAC or hypoadrenocorticism testing)
b. Aldosterone is typically markedly elevated in both the pre- and post-ACTH samples
c. If hypokalemia is present, aldosterone concentration should be normal to low. Markedly elevated aldosterone concentration with concurrent hypokalemia suggests primary hyperaldosteronism
(1) Primary hyperaldosteronism: Increased aldosterone concentration with normal or decreased renin concentration
(2) Secondary hyperaldosteronism: Increased aldosterone concentration with increased renin concentration

E. Treatment
1. Correct hypokalemia
2. Potassium gluconate orally
3. Spironolactone
a. Potassium-sparing diuretic
b. Aldosterone receptor antagonist
4. Surgical adrenalectomy for adrenocortical tumors

DISORDERS OF CALCIUM METABOLISM

I. Normal calcium metabolism
A. Parathyroid gland secretes parathyroid hormone (PTH) when ionized calcium (iCa) falls
B. PTH acts on the kidney to cause retention of calcium
C. Ingested vitamin D is converted to 25-hydroxyvitamin D in the liver
D. PTH increases conversion of 25-hydroxyvitamin D to 1,25-dihydroxyvitamin D (calcitriol) in the kidney
E. PTH acts on bone to cause bone resorption
F. Synthesized calcitriol causes bone resorption and increases calcium absorption in the intestine
G. As iCa levels increase, PTH production decreases
H. Elevated phosphorus levels exert a negative feedback on the production of calcitriol

II. Measurement of calcium
A. Serum total calcium (tCa) is the sum of serum ionized calcium (iCa), complexed calcium (cCa), and protein-bound calcium (pCa). Ionized calcium is the most important biologically active fraction
B. tCa does not accurately predict iCa. Concentration of iCa should be measured, especially if a calcium metabolic disorder is suspected
C. Formulas to adjust tCa to protein or albumin should *not* be used as this adjustment does not improve the prediction of iCa status

III. Hypercalcemia (Table 15-1)
A. Mechanism of hypercalcemia
1. Parathyroid-dependent (primary hyperparathyroidism)
a. Parathyroid tumor secretes excess PTH causing hypercalcemia
b. The increase in ionized calcium does not turn off PTH production by the tumor
2. Parathyroid-independent
a. Ionized calcium concentration increases in serum
b. Negative feedback causes suppression of PTH production
3. Hypercalcemia can be nephrotoxic as a result of vasoconstriction of renal vasculature
4. Nephrocalcinosis can occur, especially if phosphorus concentration increases
5. Hypercalcemia causes antagonism of vasopressin (Box 15-1)

B. Clinical signs of hypercalcemia
1. Polyuria and polydipsia are the most common clinical signs in dogs, but hypercalcemia is uncommon in cats
2. Anorexia is the most common clinical sign in cats
3. Depression, weakness
4. Vomiting, diarrhea
5. Cardiac arrhythmias
6. Seizures

C. General treatment of hypercalcemia
1. Remove underlying cause
2. Volume expansion (correct dehydration)
3. Furosemide
4. Glucocorticoids
a. Decreased bone resorption
b. Decreased intestinal calcium absorption
c. Increased renal calcium excretion
5. Bisphosphonates, which act to decrease bone turnover (osteoclast poisons)
6. Calcitonin, which inhibits bone resorption

D. Primary hyperparathyroidism
1. Mechanism: Parathyroid tumor secretes PTH, which causes ionized calcium to elevate
2. Signalment
a. More common in dogs than in cats
b. Middle-aged to elderly animals

Table 15-1 Anticipated Changes in Calcemic Hormones and Serum Biochemistry Associated with Disorders of Hypercalcemia

	tCA	iCa	alb	Corr tCa	Pi	PTH	PTHrP	25(OH)-D	I,25 $(OH)_2$ –D	PTG ULS, Surgery
Primary hyperparathyroidism	↑	↑	N	N	↓N	↑N	N	N	N↑	Single↑
Nutritional secondary hyperparathyroidism	N↓	N↓	N	N↓	N↑	↑	N	↓N	N↓	Multiple↑
Renal secondary hyperparathyroidism	N↑↓	N↓	N	N	↑N	↑	N	N↓	N↓	Multiple↑
Tertiary hyperparathyroidism	↑	↑	N	↑	↑	↑	N	N↓	↓N	Multiple↑
Malignancy associated										
Humoral hypercalcemia	↑	↑	N↓	↑N	↑N	↓N	↑N	N	↓N↑	↓
Local osteolytic	↑	↑	N↓	↑N	N↑	↓N	N↑	N	N	↓
Hypervitaminosis D										
Cholecalciferol	↑	↑	N	↑	↑N	↓	N	↑	N↑	N↓
Calcitriol	↑	↑	N	↑	N↑	↓	N	N	↑	↓N
Calcipotriene	↑	↑	N	↑	↑N	↓	N	N	↓N	↓N
Hypoadrenocorticism	↑	↑	N↓	↑	↑N	↓N	N	N	↓N	N
Hypercitaminosis A	↑	↑	N	↑	N	↓	N	N	N↓	↓N
Idiopathic (cat)	↑	↑	N	↑	N↑	↓N	N	N	N↓↑	↓N
Dehydration	↑	N↑	↑N	↑N	N↑	N↓	N	N	N	N
Aluminum exposure (renal failure)	↑	↑	N	↑	↑N	↓N	N	N	N↓	N•↑↓
Hyperthyroidism (cat)	↑	↑	N	↑	N↑	N↑↓	N	N	N↓	N↑
Raisin/grape toxicity (dog)	↑	—	N	↑	N↑	—	—	—	—	—

↓, Decreased concentration; ↑, increased concentration; N, normal; tCa, serum total calcium; iCa, serum ionized calcium; alb, albumin; Corr tCa, corrected total calcium; Pi, inorganic phosphorus; **PTH**, parathyroid hormone; PTHrP, parathyroid hormone-related protein; 25 (OH)-D, 25-hydroxyvitamin D; 1,25-dihydroxyvitamin D; PTG, parathyroid gland; ULS, ultrasound.

 c. Usually due to a solitary parathyroid adenoma
 d. Often palpable in cats, but not palpable in dogs
 e. Breeds predisposed to primary hyperparathyroidism include the keeshond, dachshund, golden retriever, poodle, Labrador retriever
3. Clinical signs
 a. Clinical signs may occur over a long period before diagnosis
 b. Polyuria, polydipsia, weakness, lethargy, inappetance, calcium-containing urinary calculi
4. Diagnosis
 a. Visualization of parathyroid tumor with ultrasound
 b. Increased ionized calcium concentration with an inappropriately high PTH concentration

Box 15-1 Causes of Hypercalcemia

G Granulomatous disease
O Osteolytic disease
S Spurious
H Hypercalcemia of malignancy, hypoadrenocorticism, hypervitaminosis D
D Vitamin D toxicity
A Addison disease, aluminum toxicity, vitamin A toxicity
R Renal disease
N Neoplasia
I Idiopathic (cats)
T Temperature (hypothermia)

5. Treatment
 a. Removal of parathyroid tumor is treatment of choice
 b. Expect transient hypoparathyroidism and hypocalcemia post-surgery until remaining parathyroid glands can recover

E. Humoral hypercalcemia of malignancy
1. Mechanism
 a. Tumor secretes factors that result in hypercalcemia
 b. Factors that cause hypercalcemia include interleukins, tumor necrosis factor, tumor growth factor, parathyroid hormone related protein (PTHrP)
 c. Increased iCa causes suppression of PTH production (parathyroid-independent hypercalcemia)
2. Signalment
 a. Dogs
 (1) Lymphosarcoma is most common
 (2) Anal sac apocrine gland adenocarcinoma
 (3) Thymoma
 (4) Carcinomas
 (5) Hematologic malignancies
 b. Cats
 (1) Lymphosarcoma and squamous cell carcinoma are most common
 (2) Multiple myeloma, osteosarcoma, fibrosarcoma, bronchogenic carcinoma, hematologic malignancies
3. Diagnosis
 a. Increased iCa concentration with suppressed PTH production
 b. If PTHrP is secreted by tumor, PTHrP will be elevated in plasma
 (1) PTHrP is similar to PTH in structure
 (2) Causes bone resorption and renal calcium conservation
 (3) PTHrP is not normally excreted in an adult animal in any appreciable amount
 (4) If PTHrP is present in any significant amount, malignancy is suspected
 (5) The absence of detectable PTHrP does not rule out malignancy

F. Hypoadrenocorticism
1. Increase in iCa concentration is usually mild
2. Parathyroid-independent hypercalcemia is seen with increased iCa concentration and suppressed PTH production
3. Magnitude of hypercalcemia parallels severity of hyperkalemia and hypovolemia
4. Hypercalcemia resolves with treatment of hypoadrenocorticism

G. Vitamin D toxicosis
1. Mechanism
 a. Oversupplementation of vitamin D
 b. Cholecalciferol rodenticide ingestion
 c. Ingestion of plants containing vitamin D metabolites (*Cestrum diurnum*)
 d. Ingestion of anti-psoriasis creams containing vitamin D metabolites
2. Clinical signs
 a. May have sudden onset
 b. May be seen in young animals
 c. Increased phosphorus concentration is seen
 d. Acute renal failure may result from nephrocalcinosis
3. Diagnosis
 a. Parathyroid-independent hypercalcemia with increased iCa concentration and suppressed PTH production
 b. 25-hydroxyvitamin D concentration
 (1) Increased with oversupplementation or rodenticide ingestion
 (2) Will be normal with plant or anti-psoriasis cream ingestion
4. Treatment
 a. Control hypercalcemia and hyperphosphatemia
 b. May need to treat for a long period because of the long half-life of ingested vitamin D compounds

H. Idiopathic hypercalcemia in cats
1. Mechanism unknown
2. Signalment
 a. Young to old cats
 b. Higher incidence in long-haired cats
3. Clinical signs
 a. Many have no clinical signs
 b. May have history of weight loss, anorexia, chronic constipation, calcium oxalate-containing uroliths
 c. May develop chronic renal failure
4. Diagnosis
 a. Parathyroid-independent hypercalcemia with elevated iCa concentration and suppressed PTH production
 b. Diagnosis by exclusion (no evidence of malignancy, parathyroid tumor, vitamin D toxicity)
5. Treatment
 a. No treatment works consistently
 b. Switch to a high fiber diet first. If that is not effective, try glucocorticoid therapy. If that is not effective, then try bisphosphonates

IV. Hypocalcemia (Table 15-2)
A. Mechanism of hypocalcemia
1. Parathyroid-dependent hypocalcemia (primary hypoparathyroidism)
 a. Destruction of parathyroid glands
 b. iCa concentration falls, but parathyroid glands are unable to secrete PTH
2. Parathyroid-independent hypocalcemia where the demand for iCa exceeds the supply or mobilization (Box 15-2)

B. Clinical signs of hypocalcemia
1. Stiff gait, muscle tremors, spasms, seizures
2. Increased anxiety, aggression
3. Intense pruritus, facial rubbing, self-mutilation

C. Primary hypoparathyroidism
1. Mechanism
 a. Lymphoplasmacytic destruction of parathyroid glands so that parathyroid glands are unable to secrete an appropriate level of PTH

Table 15-2 Anticipated Changes in Calcemic Hormones and Serum Biochemistry Associated with Disorders of Hypocalcemia

	tCa	iCa	alb	Corr tCa	Pi	PTH	PTHrP	25(OH)-D	$1,25(OH)_2$ - D	PTG ULS, Surgery
Primary hypoparathyroidism	↓	↓	N	↓	↑N	↓N	N	N	N↓	Multiple↓
Pseudohypoparathyroidism	↓	N↓	N	↓	↑N	↑	N	N	N↑	N↑
Sepsis/critical care	↓N	↓	N	↓N	N↑	↑N	N	N	N	N
Ethylene glycol toxicity	↓	↓	N	↑	↑N	↑	N	N	↓N	N
Paraneoplastic	↓	↓	N	↓	↓	↑N	N	N	N	N↑
Phosphate enema	↓	↓	N	↓	↑	↑	N	N	N↓↑	N
Eclampsia	↓	↓	N	↓	↓	Mild↑, N	N	N	N↓	N
Hypoalbuminemia	↓	↓N	↓	N	N	N↑	N	N	N↑	N↑

↓, Decreased concentration; ↑, increased concentration; N, normal; tCa, serum total calcium; iCa, serum ionized calcium; alb, albumin; Corr tCa, corrected total calcium; Pi, inorganic phosphorus; PTH, parathyroid hormone; PTHrP, parathyroid hormone related protein; 25(OH)-D, 25-hydroxyvitamin D; 1,25(OH)2-D, 1,25-dihydroxyvitamin D; PTG, parathyroid gland; ULS, ultrasound.

 b. Iatrogenic hypoparathyroidism
 (1) Parathyroid glands damaged or removed during surgery of the neck
 (2) Common in hyperthyroid surgery or post-parathyroid adenoma removal
 (3) May be transient, or require treatment for life
2. Signalment
 a. Uncommon in dogs and rare in cats
 b. More common in young adults
 c. Breeds predisposed include miniature schnauzer, miniature poodle, terriers, Siamese cats

Box 15-2 Causes of Hypocalcemia

M Magnesium depletion, malabsorption
A Albumin ↓, atrophy of parathyroid gland
T Trauma
C Chelation, critical care, calcitonin
H Hypoparathyroidism, hypoproteinemia hypomagnesmia
I Infarct of parathyroid gland
N Nutritional (Ca ↓, P ↑, Vit D ↓)
G Gastrointestinal disease (malabsorption, pancreatitis)
D Drugs, diet
R Rhabdomyolysis, renal failure
A (see A above)
P Parathyroid atrophy, destruction; pancreatitis; phosphate enemas, periparturient
E Eclampsia, ethylene glycol, enema
S Sepsis

3. Diagnosis is based on finding decreased iCa concentration with an inappropriately low PTH concentration
4. Treatment
 a. Acute
 (1) 10% calcium gluconate administered intravenously (IV)
 (2) Avoid fluids containing lactate, bicarbonate, or acetate
 (3) Do not give calcium-containing fluids subcutaneously
 b. Maintenance
 (1) Treat with both calcium and vitamin D supplementation
 (2) Oral calcium 50 to 100 mg elemental calcium/kg/day
 (3) Vitamin D preparations
 (a) Ergocalciferol is the poorest choice, longest-acting
 (b) Dihyrotachysterol (off the market)
 (c) Calcitriol is the best choice for treatment at 30 to 60 ng/kg/day. Calcitriol has the shortest onset of action and is the shortest acting
 c. Hypercalcemia can occur with treatment

D. Puerperal tetany (eclampsia)
1. Seen in the lactating bitch or queen during the first 3 weeks postpartum
2. Most common in small dogs
3. Rapidity of calcium utilization overwhelms the ability to maintain normal iCa concentration
4. Supplementation of pregnant bitch with calcium may predispose the lactating bitch to hypocalcemia (as a result of atrophy of the parathyroid glands)

E. Acute pancreatitis
1. Hypocalcemia is typically mild
2. Clinical signs of hypocalcemia are unlikely

3. Hypocalcemia is caused by the saponification of peripancreatic fat following leakage of lipase

V. Secondary hyperparathyroidism
 A. Mechanism of secondary hyperparathyroidism
 1. Secondary hyperparathyroidism is characterized by excessive bone resorption and osteopenia
 2. It is typically due to either nutritional deficiencies or chronic renal failure
 B. Diagnosis
 1. An elevated serum PTH concentration is observed, with a normal or decreased iCa concentration
 2. Concentration of 25-hydroxyvitamin D may be low in cases of nutritional secondary hyperparathyroidism
 C. Nutritional secondary hyperparathyroidism
 1. Due to diets with excessive phosphate or inadequate calcium and vitamin D content. Deficient diets are typically homemade diets made primarily with meat
 2. Clinical signs include bone pain, lameness, limb deformities, fractures
 3. More common in young, growing animals
 4. Can also occur in cases of gastrointestinal disease, causing decreased absorption of calcium or vitamin D
 5. Treat by providing a balanced diet
 D. Renal secondary hyperparathyroidism
 1. Progressive reduction in renal tubule cells with a decrease in calcitriol production
 2. Decreased ability to retain calcium by the kidneys
 3. Decreased calcitriol causes a decrease in iCa
 4. PTH secretion increases in response, resulting in increased resorption of calcium from bone, particularly in the bones of the skull ("rubber jaw")
 5. Excess PTH is a uremic toxin and contributes to neurologic signs of CRF
 6. Calcitriol therapy (2.5-3.0 ng/kg/day) to decrease production of PTH and decrease bone resorption. Serum phosphorus must be controlled for maximal effectiveness of calcitriol

DISORDERS OF GLUCOSE METABOLISM

I. Diabetes mellitus (DM)
 A. Pathogenesis
 1. Dogs
 a. Most have insulin-dependent DM (IDDM) with decreased serum insulin concentration and no increase in insulin after the administration of glucose
 b. Non-insulin-dependent DM (NIDDM) is very uncommon in dogs
 2. Cats
 a. Many have NIDDM
 b. May become permanently insulin-dependent
 B. Signalment
 1. Dogs
 a. Age: Peak incidence at 7 to 9 years
 b. Breeds
 (1) Genetic basis in keeshond
 (2) Other predisposed breeds include miniature and toy poodle, dachshund, miniature schnauzer, beagle, puli, Cairn terrier, miniature pinscher
 c. Gender: More common in females
 2. Cats
 a. Incidence is approximately 0.5%
 b. More than 50% are older than 10 years
 c. Obesity increases the risk threefold to fivefold
 d. Gender
 (1) Neutered cats are at twice the risk for developing DM
 (2) Male cats have an increased risk
 C. Clinical signs
 1. Usually do not develop until blood glucose concentration is greater than 180 to 200 mg/dL in dogs and 200 to 280 mg/dL in cats
 2. Polyuria and polydipsia, polyphagia
 3. Weight loss (usually rapid) is common in dogs
 4. Acute blindness due to cataracts
 5. Nonspecific physical examination findings include dehydration, muscle wasting, cataracts in 40% of dogs, hepatomegaly
 D. Clinical pathology findings
 1. Fasting hyperglycemia and glycosuria
 2. Hypercholesterolemia, hypertriglyceridemia (fasting hyperlipidemia)
 3. Increased liver enzymes (ALP, ALT)
 4. Neutrophilic leukocytosis
 5. Proteinuria, increase USG
 E. Diagnosis
 1. Persistent fasting hyperglycemia and glycosuria
 2. Presence of ketonuria confirms diabetic ketoacidosis (DKA)
 3. Mild hyperglycemia (less than 180 mg/dL) associated with polyuria and polydipsia is most likely not due to DM
 4. Severe hyperglycemia can occur in acutely stressed cats
 5. In IDDM, glucose concentration is increased with a decrease in insulin
 6. In NIDDM, glucose concentration is increased with a low, normal or increased insulin concentration (Box 15-3)
 F. Therapy
 1. Goal of therapy is to eliminate clinical signs and development of complications and prevent hypoglycemia
 2. Dietary therapy
 a. Correct obesity if present
 b. Maintain consistent times and content of meals
 c. Feed high-fiber diet (only if not thin)
 3. Exercise: Maintain constant daily exercise
 4. Oral hypoglycemic drugs
 a. Only for NIDDM in cats
 b. Glipizide 2.5 mg twice daily with food
 c. If hyperglycemia persists or recurs, switch to insulin therapy

Box 15-3 Causes of Hyperglycemia

S Stress (cat), steroids
C Cushing disease (hyperadrenocorticism)
R Renal disease
A Acromegaly (cat)
P Postprandial, pancreatitis, pheochromocytoma (dogs), progesterone, parenteral nutrition
E Exocrine pancreatic insufficiency, eating
D Diabetes mellitus, diestrus (dog), drugs (glucocorticosteroids, progesterone, megestrol acetate, thiazide diuretics), dextrose-containing fluids

5. Insulin therapy
 a. Types of insulin
 (1) Short-acting
 (a) Regular
 (b) Semi-Lente
 (2) Intermediate-acting
 (a) Neutral protamine Hagedorn (NPH) or isophane
 (b) Lente
 (3) Long-acting
 (a) Ultralente
 (b) Protamine zinc insulin (PZI)
 (c) Glargine
 b. Dogs
 (1) Insulin is best given twice daily
 (2) Lente or NPH preferred
 (3) Use human or porcine origin; beef origin may induce antibody formation
 (4) Initial dose is 0.5 unit/kg twice daily
 (5) Measure glucose concentration 4 and 6 to 7 hours after initial insulin
 c. Cats
 (1) Insulin best given twice daily
 (2) Lente or PZI preferred (human or beef origin)
 (3) Glargine lasts 12 to 16 hours in cats and takes several days for maximum effect
 (4) 1 to 3 units/cat twice daily initially
 (5) May need to decrease dose after 2 weeks, especially if using glargine
 (6) Measure glucose concentration 4 and 6-7 hours after initial insulin
 (7) Cats requiring high doses during initial treatment usually have poor absorption (switch to PZI or Lente)
6. Monitoring treatment (Figure 15-2)
 a. Monitor clinical signs such as appetite, water consumption, urination, activity, general well-being
 b. Glucose curves
 (1) Perform during initial regulation, when hypoglycemia is suspected, and in poorly controlled DM
 (2) Procedure
 (a) Feed before test
 (b) Obtain blood glucose
 (c) Administer insulin

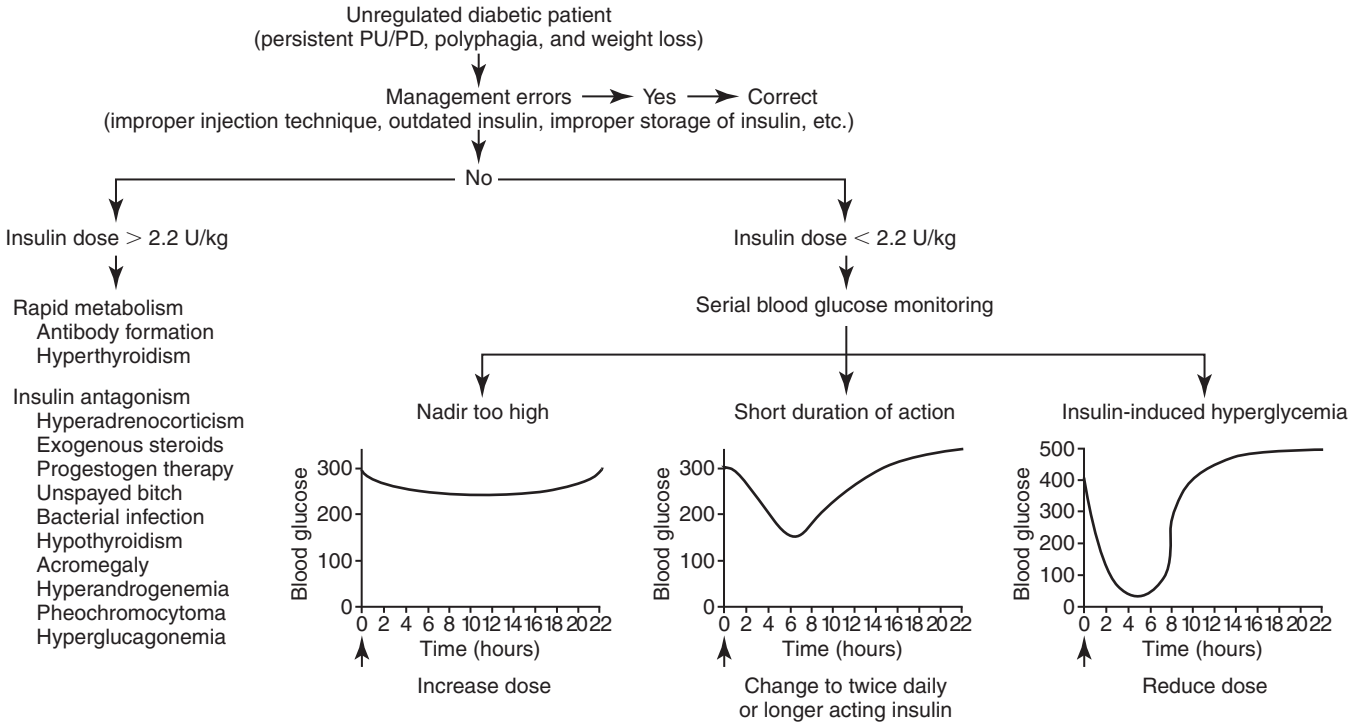


Figure 15-2 Algorithm for the unregulated diabetic dog or cat. (From Miller E. Long-term monitoring of the diabetic dog and cat: Clinical signs, serial blood glucose determinations, urine glucose, and glycated blood proteins. *Vet Clin North Am Small Anim Pract* 25:582, 1995; with permission.)

(d) Measure blood glucose concentration every 2 hours until 8 to 12 hours after insulin (if giving insulin twice daily)
(3) Interpretation
(a) Maintain glucose between 100 and 200 mg/dL in dogs and 100 and 250 mg/dL in cats
(b) Glucose nadir should be between 80 and 120 mg/dL. The time of nadir indicates peak insulin action. The nadir should occur approximately halfway through the dosing interval
(c) Glucose differential is the difference between the glucose nadir and blood glucose just before the next insulin dose. The differential should be less than 100 mg/dL in dogs without cataracts, and less than 150 mg/dL in dogs with cataracts
(d) If the glucose nadir is too high, increase the dose of insulin
(e) If the nadir occurs too soon, change to a longer-acting insulin
(f) If the nadir occurs too close to next dose of insulin, change to a shorter duration of insulin
(4) Somogyi effect
(a) Insulin concentration is too low at the nadir and induces stress hormone release
(b) Marked hyperglycemia can occur as a result
(c) Poor control of DM due to too much insulin
(d) Decrease insulin dose by 25%
(e) Repeat glucose curve 1 week after altering insulin dose
c. Other monitoring methods
(1) Urine glucose concentration
(2) Glycosylated hemoglobin
(3) Fructosamine reflects blood glucose over the previous 5 to 8 days and cannot detect hypoglycemia, so Somogyi effect will look like poor control

G. Complications
1. Insulin resistance
a. Inadequate control of glucose with insulin doses greater than 2 units/kg/day
b. Factors contributing to insulin resistance include obesity, HAC, hypothyroidism, development of insulin antibodies, and acromegaly in cats. It can be difficult to diagnose HAC when DM is present because the stress of diabetes often causes false-positive adrenal function test results
2. Hypoglycemia
a. Common complication of insulin therapy
b. May occur following an increase in insulin dose, strenuous exercise, or prolonged inappetence
c. Signs include ataxia, weakness, lethargy, seizures
d. Treat with glucose administration (food, sugar water, or IV dextrose)
3. DKA
a. Occurs most commonly in dogs and cats with previously undiagnosed DM
b. May occur in patients receiving inadequate insulin and a concurrent infection, inflammation, or insulin-resistant disorder
c. Clinical signs may develop over time. The time from onset of signs to development of DKA ranges from a few days to more than 6 months
(1) Once ketoacidosis develops, severe illness occurs within 7 days
(2) Clinical signs include dehydration, depression, weakness, tachypnea, vomiting, abdominal pain, odor of acetone on the breath, slow and deep breathing
d. Diagnosis is based on the presence of fasting hyperglycemia, glucosuria, and ketonuria
e. Treatment
(1) If signs are mild, use short-acting regular insulin three times daily until ketonuria resolves. Give one third the daily food ration at the same time as insulin
(2) If systemically ill, blood glucose is greater than 500 mg/dL, or severe metabolic acidosis is present, treat more aggressively. Aggressive therapy involves fluid therapy with potassium and phosphate supplement, bicarbonate therapy, insulin therapy with short-acting regular insulin, and additional ancillary therapy if concurrent conditions are present
f. Prognosis
(1) Approximately 30% with severe DKA die or are euthanized
(2) Death is usually due to severe metabolic acidosis

II. Insulinoma
A. Etiology
1. Uncommon in dogs; rare in cats
2. Occurs in middle-aged to older dogs. The average age is 9 years, with a range of 2.5 to 15 years
3. Medium-breed to larger-breed dogs are predisposed
4. Tumor of pancreatic β-cells, which secrete insulin; usually malignant
B. Clinical signs
1. Clinical signs may be episodic and are more common after eating, excitement, and exercise
2. Clinical signs include lethargy, weakness, ataxia, dementia, seizures, coma, death
3. Weight gain may be noted
4. Subclinical polyneuropathies such as facial paralysis or proprioceptive deficits may be present
C. Causes of hypoglycemia
1. Artifact (serum left on clot)
2. Congenital enzyme deficiency (glycogen storage disease)

3. Hunting dog hypoglycemia
4. Hepatic disease (liver failure, vascular shunts)
5. Sepsis
6. Polycythemia
7. Nonpancreatic tumors (hepatic carcinoma, leiomyosarcoma)
8. Growth hormone (GH) deficiency
9. Hypoadrenocorticism
10. Insulinoma
11. Administration of insulin or drugs
12. Toxins

D. Diagnosis
1. Hypoglycemia with an inappropriately high insulin level
2. Animal should be fasted before testing, as the normal response to feeding is insulin release
3. Blood glucose below 60 mg/dL (3.3 mmol/L) should inhibit insulin release

E. Treatment
1. Surgical
a. Monitor glucose concentrations because handling of tissue can cause insulin release
b. Pancreatitis is common post-surgery
c. Up to 50% have metastatic disease at time of surgery
2. Dietary
a. Diet high in fat, protein, and complex carbohydrates
b. Feed small meals frequently, limit exercise
3. Medical
a. Glucocorticoids
(1) Insulin antagonist
(2) Increases gluconeogenesis
b. Diazoxide
(1) Decreases insulin release from β-cells
(2) Effective in 85% of cases, expensive
c. Octreotide
(1) Inhibits insulin synthesis
(2) Patients become refractory

F. Prognosis
1. Short-term prognosis is good; long-term prognosis is guarded to poor
2. Mean survival time if treated medically is 12 months
3. If metastasis is present at time of surgery, prognosis is poor

DISORDERS OF GROWTH HORMONE

I. Growth hormone (GH) deficiency
A. Pathogenesis
1. Congenital deficiency of GH
2. Associated with congenital cystic distention or persistence of craniopharyngeal duct (Rathke's pouch), especially in brachycephalic breeds
3. Deficiencies of other pituitary hormones may also be present (TSH, ACTH, lutenizing hormone [LH], follicle-stimulating hormone [FSH])

B. Signalment
1. Primarily in the German shepherd, Weimaraner, spitz, Carnelian bear dog; also seen in cats
2. Simple autosomal recessive mode of inheritance in German shepherd dog and Carnelian bear dog

C. Clinical signs
1. Lack of growth (short stature) with normal body proportions
2. Testicular atrophy in males, no estrus activity in females
3. Retention of secondary hairs with absence of primary hairs
a. Soft and wooly initially (puppy coat), but this hair is easily epilated, so alopecia develops
b. Skin becomes hyperpigmented, thin, and scaly, with secondary pyoderma
4. Mental dullness
5. Bone deformities
6. Delayed growth plate closure
7. Delayed eruption of teeth

D. Clinical pathology findings
1. Findings are usually normal if the deficiency is uncomplicated
2. If there are signs related to deficiencies of other pituitary hormones (e.g., hypoadrenocorticism, hypothyroidism), there may be clinical pathology findings typical of these other conditions

E. Diagnosis
1. Insulin-like growth factor 1 (IGF-1) concentration is usually low, especially for a young age
2. Breed differences do exist, so an age-matched control for IGF-1 determination is useful

F. Treatment
1. Injections of GH
2. Skin and hair responds within 6 to 8 weeks of GH therapy
3. There is usually no appreciable growth

G. Prognosis is poor. Most live only 3 to 8 years

II. Acromegaly
A. Pathogenesis
1. Acromegaly is due to an excess of GH production
2. In cats, this is usually caused by a pituitary functional neoplasia
3. In dogs, acromegaly due to pituitary functional neoplasia is very rare. Most often, acromegaly is related to an excess of progesterone (either endogenous or exogenous) which induces the systemic release of GH from mammary tissue

B. Signalment
1. Acromegaly is more common in male cats
2. Usually older cats (8-14 yrs old)

C. Clinical Signs
1. Acromegaly is usually considered only when insulin is ineffective at controlling hyperglycemia
2. Polyuria and polydipsia are the earliest clinical signs
3. Weight gain is an important sign in poorly controlled diabetics
4. Increased size
5. Enlargement of head, extremities, feet, abdomen, heart, viscera

6. Broad face, widened interdigital spaces
7. Inspiratory stridor, panting, apnea
8. Neurologic signs as a result of expanding pituitary tumor

D. Clinical pathology
1. Poorly controlled DM (hyperglycemia, glucosuria)
2. Persistent hyperproteinemia

E. Diagnosis
1. Elevated concentration of IGF-1 accompanied by appropriate clinical signs. IGF-1 production parallels GH production and can be used as a measure of GH concentration
2. Elevated concentrations of IGF-1 also occur in association with DM, so caution should be exercised in diagnosing acromegaly in a diabetic cat that does not have strong clinical signs
3. The presence of acromegaly may result in insulin-resistant DM or poor control of existing diabetes
4. Documentation of pituitary mass in cats by computed tomography or magnetic resonance imaging

F. Treatment
1. Radiation therapy of the pituitary mass has limited availability, and acromegaly often recurs 6 to 18 months later
2. Surgery to remove a pituitary mass has very limited availability
3. In dogs, treatment is to remove the source of progesterone (ovariohysterectomy)
4. Manage long-term consequences in the cat, such as chronic renal failure, heart failure, insulin resistance

G. Prognosis: Long-term prognosis is poor, with survival of 4 to 42 months

OTHER ENDOCRINE DISORDERS

I. Diabetes insipidus (DI)

A. Pathogenesis
1. Primary DI (central DI [CDI])
 a. Defective synthesis or secretion of vasopressin by the hypothalamus
 b. May be idiopathic or due to head trauma, neoplasia, hypothalamic or pituitary malformations
2. Secondary DI (nephrogenic DI [NDI])
 a. Renal tubules are unable to respond to vasopressin
 b. May be familial or acquired
 (1) Familial NDI is a rare congenital disorder
 (2) Acquired NDI is the most common form of DI

B. Signalment
1. No breed, gender, or age predilection in dogs
2. In cats, most are domestic short hair (DSH) or domestic long hair (DLH); documented in Persians and Abyssinians
3. Primary DI is usually diagnosed in puppies, kittens, or young adults

C. Clinical signs
1. Polyuria or polydipsia
2. Animals may appear incontinent
3. Neurologic signs may be seen with CDI as a result of head trauma or tumors or if dehydrated
4. Animals may be thin because they would rather seek water than eat

D. Diagnosis
1. Rule out other causes of polyuria and polydipsia and acquired NDI (e.g., HAC, hypercalcemia, hyperthyroidism, DM, acromegaly)
2. Urine is usually hyposthenuric, but isosthenuria (USG 1.008 to 1.012) does not rule out DI
3. Hypernatremia with hyposthenuria raises suspicion for DI
4. Differentiating absolute and partial CDI
 a. Absolute vasopressin deficiency causes persistent hyposthenuria and severe diuresis even if dehydrated
 b. In partial CDI, animals can increase USG into isosthenuric range but typically not above 1.015
5. Modified water deprivation test
 a. Assesses the effects of water deprivation and dehydration on USG
 b. Do not perform if animal is dehydrated or has compromised renal function
 c. Normal animals or those with psychogenic water consumption should be able to concentrate urine to greater than 1.030
 d. Animals with CDI or familial NDI cannot concentrate urine when dehydrated
6. Response to desmopressin (dDAVP, synthetic vasopressin)
 a. Give one to four drops dDAVP into conjunctival sac once or twice daily for 5 to 7 days
 b. See marked increase in USG in animals with CDI
 c. Minimal improvement in those with NDI

E. Treatment
1. For CDI, dDAVP is either administered in the conjunctival sac once or twice daily, or it is given parenterally
2. No treatment really necessary as long as there is a constant water supply

II. Gastrinoma

A. Etiology
1. Pancreatic tumor secreting primarily gastrin
2. Usually malignant

B. Signalment
1. Age at presentation
 a. Dogs: Mean age is 7.5 years (range, 3 to 12 years)
 b. Cats: Mean age is 11 years
2. No breed predisposition
3. Females may be more commonly affected than males

C. Clinical signs
1. Vomiting and weight loss are most common
2. Depression, lethargy, diarrhea, hematemesis, melena, abdominal pain, collapse

D. Diagnosis
 1. Complete blood cell count (CBC)-biochemistry profile: Regenerative anemia, leukocytosis, hypochloremia, hypokalemia, hypoalbuminemia, hypoproteinemia, mild increase in liver enzymes
 2. Elevated gastrin concentration
 a. Must rule out other causes of elevated gastrin concentration
 b. Causes of elevated gastrin include gastrinoma, renal failure, pyloric stenosis, hypochlorhydria, atrophic gastritis, small intestinal resection, liver disease, gastric dilatation and volvulus, administration of antacids, histamine type 2 blockers, proton pump inhibitors, or glucocorticoids, immunoproliferative enteropathy of basenjis
E. Treatment
 1. Surgical resection is the treatment of choice
 a. Mass is small and may be difficult to locate
 b. Usually malignant
 2. Reduce gastric acid secretion
 a. Histamine type 2 receptor antagonists (cimetidine)
 b. Proton pump inhibitors (omeprazole)
 c. Octreotide suppresses gastrin release by the tumor and inhibits gastrin stimulation of parietal cells

III. Pheochromocytoma
A. Pathogenesis
 1. Catecholamine-producing tumor of the adrenal medulla
 2. Malignant, slow-growing
 3. Commonly invade vena cava
 4. Metastases to liver, lung, lymph nodes, spleen, heart, kidney, bone, pancreas, central nervous system
B. Signalment
 1. Uncommon in dogs, rare in cats; often incidental
 2. Older dogs (mean age 11 years)
 3. No sex or breed predilection
C. Clinical signs
 1. Clinical signs are related to excess secretion of catecholamines, space-occupying nature of the tumor, or metastatic lesions
 2. Catecholamine secretion is sporadic and unpredictable, so clinical signs may be episodic
 3. Size of the tumor correlates to severity of clinical signs
 4. Common clinical signs include the following:
 a. Collapsing episodes
 b. Weakness
 c. Panting or tachypnea
 d. Polyuria or polydipsia
 e. Lethargy
 f. Vomiting
 g. Inappetance
 5. Other clinical signs include anxiety, agitation, diarrhea, abdominal distention, hemorrhage, acute blindness, tremors, weight loss, tachycardia, rear limb edema, or no clinical signs
D. Differential diagnosis
 1. Nonfunctional adrenal mass
 2. HAC due to an adrenal tumor
 3. HAC can occur simultaneously with pheochromocytoma
E. Diagnosis
 1. No consistent abnormalities on CBC, chemistry profile, or urinalysis
 2. History of episodic collapse
 3. Identification of an adrenal mass
 4. Documentation of hypertension in nonazotemic dogs with adrenal mass and normal adrenocortical function. Hypertension may be life-threatening
 5. Urinary catecholamine concentration or metabolites are increased
F. Treatment
 1. Medical treatment to control hypertension
 a. Phenoxybenzamine
 b. Mitotane is ineffective
 2. Follow with surgery 1 to 2 weeks after initiating medical treatment
 a. Surgery is difficult
 b. Many tumors invade surrounding vessels
 c. Manipulation of tumor can cause severe hypertension and tachycardia
 d. Look for metastases
 e. Postoperative complications are common
G. Prognosis
 1. Depends on the size of the mass, presence of metastases, or local invasion into adjacent blood vessels or kidney
 2. When tumors are surgically excised, the prognosis is guarded to good (2 months to 3 years)
 3. Dogs treated medically may live longer than a year if the tumor is small, vascular invasion is not present, and hypertension can be controlled

Supplemental Reading

Greco D. Diabetes mellitus. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 376-389.

Kintzer PP, Peterson ME. Diseases of the adrenal gland. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 357-375.

Panciera DL, Peterson ME, Birchard SJ. Diseases of the thyroid gland. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 327-342.

Randolph JF, Nichols R, Peterson ME. Diseases of the hypothalamus and pituitary. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 398-408.

Reine NJ, Bonczynski J. Pancreatic beta cell neoplasia. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 390-397.

Schenck, PA, Chew DJ. Diseases of the parathyroid gland and calcium metabolism. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 343-356.

Schenck PA, Chew DJ, Behrend EN. Updates on hypercalcemic disorders. In August J, ed. *Consultations in Feline Internal Medicine.* St Louis, 2005, Saunders, pp. 157-168.

Schenck PA, Chew DJ, Nagode A, Rosol TJ. Disorders of calcium: Hypercalcemia and hypocalcemia. In Dibartola S, ed. *Fluid Therapy in Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 122-194.

16 CHAPTER

Gastrointestinal Disorders

Michal Mazaki-Tovi

ORAL DISORDERS

I. Oronasal fistulas and palatal defects
 A. Congenital defect in brachiocephalic breeds, miniature schnauzers, cocker spaniels, beagles, and cats
 B. Acquired defect from trauma or maxillary periodontal pocket
 C. Clinical signs include sneezing after eating and mucopurulent nasal discharge
 D. Diagnosis is by physical examination
 E. Surgery is treatment of choice

II. Stomatitis and gingivitis
 A. Etiology includes periodontal disease, physical injury, chemical injury, systemic infections (herpesvirus, calicivirus in cats; *Nocardia* in dogs), oral candidiasis, necrotizing ulcerative stomatitis, immunosuppression secondary to feline leukemia virus (FeLV) or feline immunodeficiency virus (FIV), uremia, plasma cell stomatitis (cats), feline eosinophilic granuloma complex, canine oral eosinophilic granuloma, autoimmune disorders, niacin deficiency, or oral neoplasia
 B. Clinical signs include hypersalivation, halitosis, oral bleeding, dysphagia, anorexia, and weight loss
 C. Diagnosis by history and physical examination primarily. Radiographs and laboratory tests may help to identify the underlying cause
 D. Treatment
 1. Treat the underlying cause
 2. Symptomatic treatment includes dental prophylaxis, systemic antibiotics

III. Tonsillitis
 A. Primary tonsillitis may occur in young, small-breed dogs, or tonsillitis may be secondary to chronic infections of the nasopharynx, vomiting, chronic regurgitation, or coughing
 B. Clinical signs include retching, cough, fever, and anorexia
 C. Diagnosis is based on physical examination and history
 D. Treat with antibiotics, and treat the underlying disorder

IV. Tonsillar neoplasia
 A. Squamous cell carcinoma and lymphoma are the most common causes
 B. Clinical signs may include retching, coughing, and cervical mass (metastases to regional lymph nodes)
 C. Diagnosis is based on oral examination and biopsy findings
 D. Treat with chemotherapy
 E. Prognosis is poor

V. Salivary gland diseases
 A. Causes
 1. Mucoceles (sialoceles) result from damage to the duct or gland and leakage of saliva into the tissues. Common sites include cervical and sublingual (ranulas) mucoceles
 2. Fistulas are common and usually the result of trauma to the parotid salivary gland or duct
 3. Sialoadenitis is uncommon and usually affects the zygomatic salivary gland
 4. Sialoadenosis is a syndrome of unknown cause in dogs, characterized by mandibular salivary gland enlargement, associated with hypersalivation, retching, regurgitation, and vomiting. Response to phenobarbital is often excellent
 5. Neoplasia of the salivary glands is rare
 B. Clinical signs
 1. Clinical signs of mucoceles depend on the gland affected. Cervical mucoceles present as soft nonpainful masses; ranulas cause dysphagia and blood-tinged saliva; pharyngeal mucocele may cause breathing or swallowing difficulty; and zygomatic mucoceles may cause exophthalmos
 2. Fistulas present as a small skin opening draining serous fluid
 3. Zygomatic sialoadenitis causes exophthalmos, pain on opening the mouth, and mucopurulent discharge from the duct. Parotid sialoadenitis presents as a painful, warm parotid gland and discharge
 4. Sialoadenosis is usually associated with chronic signs, including hypersalivation, retching, regurgitation, and vomiting
 5. Neoplasia usually presents as a nonpainful mass in the region of the salivary gland
 C. Diagnosis
 1. The diagnosis of mucoceles is usually based on palpation and aspiration of viscid, mucinous fluid that is consistent with saliva
 2. Sialography may be used to diagnose fistulas but is usually not necessary
 3. Sialoadenitis is diagnosed based on complete blood cell count (CBC) and histopathology findings

4. Sialoadenosis is a diagnosis of exclusion. Cytologic and histologic evaluations of the salivary glands are unremarkable. A dramatic rapid response to phenobarbital supports the diagnosis

D. Treatment
1. Cervical mucoceles are treated by surgical excision of the mandibular and sublingual salivary glands (for cervical and pharyngeal mucoceles) or zygomatic salivary gland (for zygomatic mucocele). Ranulas may be treated by surgical marsupialization
2. Sialoadenitis: Treat with systemic antibiotics, drainage of the abscess, and application of warm compresses
3. Sialoadenosis: Treat with long-term therapy (phenobarbital or potassium bromide) is usually required
4. Neoplasia: Treat with surgical removal. Postoperative chemotherapy, radiation therapy, or both may be beneficial for adenocarcinoma

ESOPHAGUS AND DISORDERS OF SWALLOWING

I. Overview
A. Cause is either a structural disorder or a motility disorder
B. Clinical signs include regurgitation, dysphagia, odynophagia, ptyalism, exaggerated swallowing, weight loss, polyphagia, anorexia, cough, dyspnea, and fever
C. Diagnosis is based on history and a careful physical examination to detect alterations of swallowing. Imaging is most important for the diagnosis. Endoscopy can also be used. Consider *Spirocerca lupi* infection in the southern United States
D. Treatment includes specific therapy for the underlying condition, along with general symptomatic management

II. Oropharyngeal dysphagia
A. Causes
1. Oral dysphagia involves difficulty with prehension or transport of food to the pharynx
2. Pharyngeal dysphagia involves problems with transport of a bolus from the oropharynx through the cranial esophageal sphincter and includes cricopharyngeal achalasia and cricopharyngeal asynchrony
3. Caused by morphologic (e.g., foreign body, dental disease, oral neoplasia, stomatitis, retropharyngeal abscess, cleft palate, etc.) or functional (e.g., neuromuscular) disorders

B. Clinical signs
1. Oral dysphagia is characterized by abnormal prehension and mastication
2. Pharyngeal dysphagia is characterized by repeated unsuccessful attempt to swallow with gagging, retching, and spitting of food. Aspiration pneumonia is common
3. Regurgitation may occur with concurrent megaesophagus and generalized muscle weakness, or neurologic deficits may occur when there is an underlying neuromuscular disorder

C. Diagnosis
1. Signalment may suggest breed dispositions for congenital neuromuscular disorders (e.g., hereditary muscular dystrophy in Bouvier)
2. Morphologic diseases can be detected by visual examination of the oropharynx, and generalized neuromuscular abnormalities may be detected by complete physical and neurologic examination
3. Imaging
a. Radiographs of the oropharyngeal area may identify morphologic disorders (e.g., foreign body)
b. Thoracic radiographs may reveal aspiration pneumonia or concurrent megaesophagus
c. Fluoroscopy with a barium swallow is required for the diagnosis of functional abnormalities
d. Ancillary testing is usually required for the diagnosis of generalized neuromuscular disorders

D. Treatment and prognosis depend on the underlying disorder. Administer supportive treatment as needed

III. Esophageal hypomotility
A. Causes
1. May be segmental or diffuse (megaesophagus); congenital or acquired
2. Megaesophagus is idiopathic in most dogs
3. Acquired megaesophagus may occur secondary to diseases causing diffuse neuromuscular dysfunction (e.g., myasthenia gravis, dysautonomia, polyneuropathy, polymyositis, botulism, tick paralysis, anticholinesterase, lead, or thallium toxicity, hypothyroidism, hypoadrenocorticism), esophagitis, or hiatal hernia (common in cats)

B. Regurgitation is the primary clinical sign and may not be related to eating. Dyspnea, cough, and fever suggest aspiration pneumonia. Signs of an underlying disorder may be present
C. Diagnosis: Idiopathic megaesophagus is a diagnosis of exclusion
1. Signalment and history
a. Breeds predisposed for idiopathic megaesophagus include German shepherd dog, Great Dane, greyhound, golden retriever, Labrador retriever, Irish setter, miniature schnauzer, Newfoundland, shar-pei, wire-haired fox terrier, and Siamese cat
b. Congenital disorders are suggested when signs are first noted at the time of weaning
c. History of chronic or recurrent respiratory infections may indicate secondary aspiration pneumonia
2. Physical examination
a. May be unremarkable except for weight loss. Distension of the cervical esophagus may become evident by compressing the thorax while the nostrils are closed
b. Nasal discharge and additional signs associated with underlying disorders may be present

3. Imaging
 a. Survey and contrast thoracic radiography may suggest megaesophagus and aspiration pneumonia (as described above)
 b. Barium swallow fluoroscopy can detect esophageal motility disorders
4. Routine laboratory tests
 a. A CBC may reveal neutrophilia and a left shift with aspiration pneumonia
 b. Biochemical profile may reveal abnormalities associated with underlying disorders
 c. Acetylcholine receptor antibody titer to evaluate for acquired myasthenia gravis is indicated even in the absence of generalized signs, as myasthenia gravis may be focal
5. Ancillary tests to evaluate for underlying causes as indicated
6. Esophagoscopy is indicated when an obstructive disease or reflux esophagitis is suspected

D. Treatment is symptomatic and supportive in most cases
1. Feed frequent small meals with the animal in an upright position. Liquid food is better tolerated in most cases, but different food types should be tried to identify the best option. Gastrostomy tube may be required in some cases
2. Administer antibiotic therapy for aspiration pneumonia

E. Idiopathic Megaesophagus is usually irreversible and supportive care is required for life

IV. Esophageal foreign body
A. Foreign bodies commonly found in dogs are bones and in cats vomited hairballs. These usually lodge at the thoracic inlet, base of the heart, or hiatus of the diaphragm. Complications include esophagitis, esophageal perforation and mediastinitis, esophageal stricture, and bronchoesophageal fistula
B. Clinical signs include acute onset of gagging, salivation, dysphagia, and regurgitation. Depression, fever, cough, and dyspnea may suggest aspiration pneumonia
C. Diagnosis is usually confirmed with radiography, barium contrast esophageal radiography, or esophagoscopy. Bones or metal foreign bodies are usually apparent on survey thoracic and cervical radiographs. Evaluate thoracic radiographs for aspiration pneumonia. Findings of pneumomediastinum, pneumothorax, and mediastinal or pleural effusion suggest esophageal perforation
D. Endoscopic removal is preferred in most cases
1. If the object cannot be extracted orally, advance it to the stomach to be removed by gastrostomy (bones may dissolve). Withhold food and water for 24 hours after the procedure. Administer antibiotics if indicated
2. An esophagotomy is indicated if the foreign body cannot be retrieved orally or advanced into the stomach

E. Prognosis is excellent unless perforation or aspiration pneumonia is present

V. Esophageal perforation
A. Foreign bodies are the most common cause; penetrating wounds are also common. Iatrogenic perforation may occur during esophagoscopy
B. Clinical signs include anorexia, depression, odynophagia, and a rigid stance. Cervical swelling, cellulitis, or a draining fistula may be present with cervical esophageal perforation. Cough, dyspnea, and fever may occur with mediastinitis or pleuritis
C. Thoracic radiography may show pneumomediastinum, pneumothorax, and mediastinal or pleural effusion. The CBC usually reveals neutrophilia with a left shift
D. Surgical repair is needed if the perforation is large, or mediastinitis or pleuritis occur
E. Medical management is sufficient for small tears. Give parenteral antibiotics, fluid therapy, and nothing per os for 5 to 7 days. Consider feeding by gastrostomy tube or parenteral nutritional support

VI. Esophagitis
A. Causes of esophagitis include foreign bodies, oral medications (doxycycline), thermal injury, caustic injury, *Pythium insidiosum* infection, and gastroesophageal reflux associated with chronic vomiting, hiatal hernia, general anesthesia, or indwelling nasogastric (NG) tube
B. Clinical signs are nonspecific for esophageal disease and may be absent with mild esophagitis
C. Esophagoscopy is the most sensitive method of diagnosis
1. Findings include mucosal erythema, hemorrhage, erosions, ulcers, strictures (in severe cases)
2. With gastroesophageal reflux, lesions are most severe in the distal esophagus, the gastroesophageal junction may appear dilated, and reflux of gastric contents into the esophagus may be noted

D. Treatment
1. General therapy involves antibiotic therapy and frequent feeding of small portions of soft food
2. For reflux esophagitis, give promotility agents (metoclopramide), histamine type 2 (H_2)-receptor blockers, sucralfate, and prednisolone

E. Prognosis is good for mild to moderate esophagitis and guarded or poor for severe esophagitis

VII. Esophageal stricture
A. Strictures may be the result of severe esophagitis or esophageal surgery
B. Regurgitation usually occurs immediately after eating, but it might not be related to eating in chronic cases
C. If due to injury, signs of stricture usually occur within 14 days
D. Radiography may show distention of the esophagus proximal to the stricture. Contrast studies or endoscopy may be helpful in the diagnosis
E. Treatment is usually by balloon catheter dilatation. Prednisolone helps prevent further fibrosis and stricture

VIII. Esophageal diverticula
- A. Diverticula are pouchlike sacculations of the esophageal wall and may be congenital or acquired. Diverticula may become impacted, leading to esophagitis
- B. Clinical signs include regurgitation, distress after eating, intermittent thoracic pain, and respiratory distress
- C. Thoracic radiography may reveal a gas- or food-filled mass in the area of the esophagus. Barium esophagram or esophagoscopy may confirm the diagnosis
- D. Large diverticula require surgical resection, but small diverticula can be managed by feeding frequent small meals of soft food with the animal in an upright position

IX. Esophageal fistula
- A. Fistulas are communications between the esophagus and airways, most commonly the bronchi. Acquired fistulas are more common than congenital fistulas and may be caused by esophageal foreign body, trauma, malignancy, or infection. Bronchoesophageal fistulas are frequently associated with esophageal diverticula
- B. Clinical signs are related to contamination of the airways with fluid and food. Coughing, fever, and dyspnea are common
- C. Diagnosis is based on physical examination findings, thoracic radiography, and confirmation with a barium esophagram
- D. Treatment is surgical resection of the fistula with appropriate antibiotic therapy
- E. Prognosis is poor if complications (e.g., pulmonary abscess, pleuritis) are present

X. Vascular ring anomalies
- A. Causes (Figure 16-1)
 1. Persistent right aortic arch (PRAA) accounts for 95% of vascular ring anomalies in dogs and cats. The right rather than the left fourth aortic arch is retained, resulting in compression of the esophagus between the ligamentum arteriosum, the aorta, the pulmonary trunk, and base of the heart
 2. There is a familial tendency in some breeds (e.g., German shepherd dog, Irish setter)
- B. Clinical signs include regurgitation that begins at the time of weaning, failure to gain weight, and cough and dyspnea (with aspiration pneumonia)
- C. Survey thoracic radiography findings suggesting PRAA include esophageal dilatation cranial to the heart, absence of the normal bulge of the aortic arch, and leftward tracheal deviation cranial to the heart. Barium esophagram may confirm the location of the esophageal obstruction
- D. Treatment involves surgical ligation and antibiotic therapy if indicated. Prognosis for recovery of esophageal function is better if the surgery is performed early

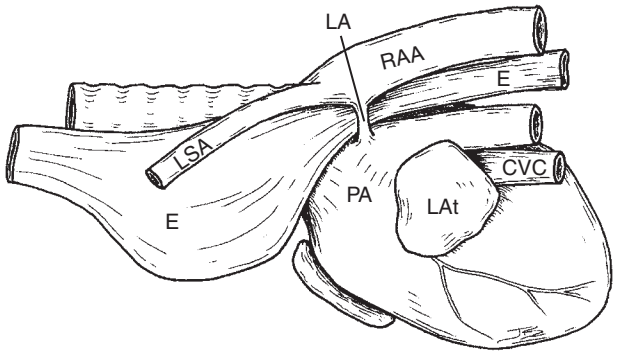


Figure 16-1 Schematic of persistent right aortic arch. This view, from the left, shows the ligamentum arteriosum *(LA)* connecting the descending right aortic arch *(RAA)* to the main or left pulmonary artery *(PA)* causing constriction of the esophagus *(E)* between these structures and the heart base. *CVC*, Caudal vena cava; *LAt,* left atrium; *LSA,* left subclavian artery. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

XI. Hiatal disorders
- A. Causes
 1. Hiatal hernias: A sliding hiatal hernia is a protrusion of the distal esophagus and stomach through an enlarged esophageal hiatus into the thorax. A congenital form has been described in shar-peis. It may also occur secondary to high positive intraabdominal pressure (e.g., abdominal trauma, vomiting), chronic upper airway obstruction (e.g., brachycephalic syndrome), or tetanus
 2. Gastroesophageal intussusception, an invagination of the stomach into the distal esophagus, is seen with congenital idiopathic megaesophagus
- B. Clinical signs of small hiatal hernias are due primarily to reflux esophagitis (regurgitation, hypersalivation). When large portions of the stomach are displaced, signs of gastric and esophageal obstruction occur and may include dyspnea, hematemesis, collapse, rapid deterioration, and death
- C. Radiography, barium esophagram, or endoscopy may confirm the diagnosis
- D. Surgery is indicated for the treatment of large hernias. Small hernias may be managed medically with treatment for reflux esophagitis and frequent feeding of small portions of low-fat soft-food diet

XII. Periesophageal obstruction
- A. Extraluminal compression can be caused by cervical or mediastinal masses
- B. Clinical signs include chronic progressive regurgitation, dysphagia, and hypersalivation in addition to other signs related to neoplasia
- C. Thoracic radiography usually reveals an intrathoracic mass
- D. Treat the underlying cause

XIII. Esophageal neoplasia
- A. Primary neoplasia is rare. Leiomyoma is the most common neoplasia in dogs, and squamous cell carcinoma is most common in cats. Osteosarcoma and fibrosarcoma in dogs may develop with malignant transformation of a granuloma caused by *Spirocerca lupi*. Other tumors occasionally metastasize to the esophagus
- B. Clinical signs include regurgitation, dysphagia, and ptyalism

C. Endoscopy and biopsy are required for a definitive diagnosis
D. Surgical excision is required

STOMACH DISORDERS

I. Vomiting
 A. A common clinical sign associated with gastrointestinal (GI) and non-GI disorders
 1. Frequently is preceded by nausea (hypersalivation, repeated licking and swallowing), retching, and abdominal contractions
 2. Vomitus consists of stomach and duodenal contents (food, mucus, and foamy or bile-stained fluid with a neutral or acidic pH) and may contain blood (hematemesis)
 3. Projectile vomiting usually indicates gastric outlet or upper small bowel obstruction
 4. Vomiting of undigested food more than 12 hours after eating suggests delayed gastric emptying
 B. Diagnosis
 1. Careful review of history and physical examination is required. Include oral and rectal examinations, abdominal palpation, review of vaccination and deworming history
 2. Laboratory evaluation includes routine hematology, biochemistry, urinalysis, and additional tests as indicated. Fecal flotation tests may be indicated
 3. Imaging
 a. Routine abdominal radiographs may identify radiopaque foreign bodies, GI obstruction, or mural thickening. Barium contrast may additionally identify radiolucent foreign bodies. Barium mixed with food and barium-impregnated plastic spheres (BIPS) may detect gastric retention disorders. Use aqueous iodide contrast if perforation is suspected
 b. Abdominal ultrasonography is useful to evaluate non-GI causes of vomiting (e.g., pancreatitis, hepatic, or renal disease) and GI disorders (e.g., intussusception, or masses)
 4. Endoscopy or exploratory laparotomy may be necessary
 C. Symptomatic and supportive treatment
 1. Fluid therapy. Intravenous therapy is preferred.
 2. Withhold food for 12 to 24 hours, then offer a highly digestible diet (chicken and rice) for 2 to 3 days. Gradually reintroduce the routine diet over 2 to 3 days
 3. Antiemetics. Phenothiazines are widely used but may decrease seizure threshold. Metoclopramide should not be used in animals with seizures. Butorphanol is also commonly used. Avoid anticholinergic drugs
II. Acute gastritis
 A. Common, usually mild and self-limiting. Possible causes include dietary indiscretion, foreign body causing mechanical irritation, chemical irritants, and drugs
 B. Clinical signs include acute onset of nausea and vomiting
 C. Diagnosis is supported by response to therapy in 1 to 2 days
 D. Treat the underlying cause, withhold food for 12 to 24 hours, then offer a bland diet. Correct dehydration if present; consider antiemetic and acid control therapy
III. Gastric foreign bodies
 A. Gastric foreign bodies are most common in dogs. Linear foreign bodies are more likely in cats
 B. The most common clinical sign is acute-onset vomiting, but some may present with chronic vomiting. Additional signs may relate to the foreign body ingested (zinc or lead toxicity)
 C. Gastric foreign body should be considered in all animals with acute vomiting. Radiography may identify the object and reveal a distended stomach
 D. Endoscopic removal is preferred. Asymptomatic animals may be managed conservatively. Perform gastrostomy if object cannot be removed via endoscopy
IV. Gastroduodenal ulceration and bleeding
 A. Causes include nonsteroidal antiinflammatory drugs (NSAIDs), glucocorticoids, chronic gastritis, hepatic disease, renal failure, neurologic disease, hypoadrenocorticism, gastric neoplasia, mast cell tumors, gastrinoma, or stress
 B. Clinical signs include anorexia, vomiting, hematemesis, melena, abdominal pain, and weight loss. Acute onset abdominal pain, depression, and collapse suggest ulcer perforation and septic shock
 C. Diagnosis
 1. Carefully review drug history for administration of ulcerogenic drugs
 2. Laboratory evaluation may show regenerative anemia or microcytic hypochromic anemia with chronic blood loss. Evaluate for underlying disorders
 3. Radiographs or GI contrast studies may be useful
 4. Abdominocentesis is indicated if perforation is suspected
 5. Endoscopy or laparotomy may be useful
 D. Treat with H_2 blockers to control gastric acid secretion, and sucralfate for mucosal protection. Give antibiotics or other supportive therapy as needed (Figure 16-2)
V. Chronic Gastritis
 A. Lymphocytic-plasmacytic gastritis is a common histologic diagnosis
 1. Etiology
 a. Idiopathic chronic gastritis is usually attributed to dietary allergy or intolerance, occult parasitism, or a reaction to bacterial antigens, or unknown pathogens
 b. Specific causes include infection with *Physaloptera rara, Ollulanus tricuspis* (cats), *Pythium insidiosum* (dogs), or *Helicobacter*, enterogastric reflux, or chronic mucosal irritation

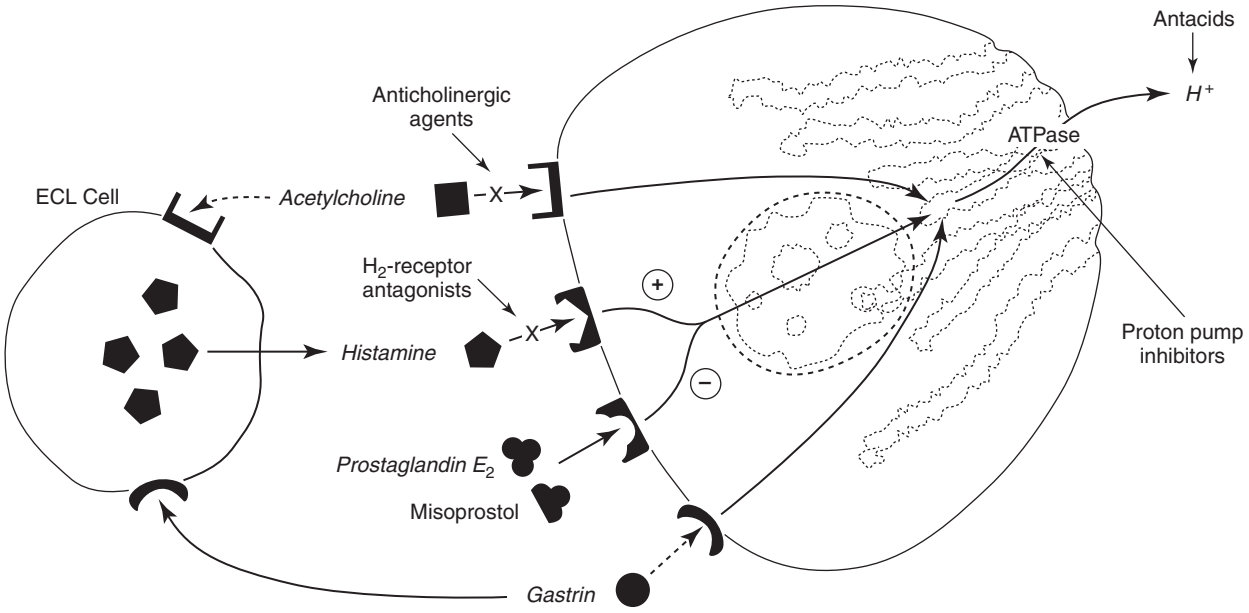


Figure 16-2 Representation of a gastric parietal cell showing the site of action of various therapeutic agents used to decrease gastric acid secretion. Histamine type 2 (H_2) antagonists (blockers) competitively inhibit acid secretion stimulated by histamine, which is released from nearby enterochromaffin-like (ECL) cells by gastrin stimulation. Acetylcholine also indirectly stimulates histamine release from the ECL cells. Use of anticholinergic drugs to inhibit acid secretion is limited by systemic side effects. Prostaglandin (PGE_2) analogues, such as misoprostol, inhibit acid secretion by blocking histamine-induced cyclic adenosine monophosphate production. Proton pump inhibitors such as omeprazole and pantoprazole have broad-spectrum antisecretory activity because they interrupt the final common pathway of acid secretion by inhibiting hydrogen potassium adenosine triphosphatase. Antacids neutralize luminal gastric acid. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice,* 3rd ed. St Louis, 2006, Saunders.)

2. Clinical signs include intermittent vomiting (weeks to months), and is not consistently associated with eating
3. Endoscopy is the diagnostic method of choice. Mucosal abnormalities include irregularity, firmness, or ulceration. Laparotomy may be indicated for biopsies

B. Eosinophilic gastritis and granuloma
1. Eosinophilic infiltration is usually diffuse but may present as a granulomatous lesion in dogs. An allergic or immunologic hypersensitivity has been suggested. Eosinophilic gastritis is rarely associated with hypereosinophilic syndrome in cats
2. Clinical signs include chronic vomiting, hematemesis, melena, anorexia, and weight loss
3. Endoscopy is the diagnostic method of choice. Laparotomy may be indicated to obtain gastric biopsies

C. Therapy for chronic gastritis
1. Treat any underlying disorder
2. Dietary trial with an easily digestible, moderately fat-restricted, carbohydrate-based diet, with a novel protein source. Feed frequent small meals, and assess response after 3 to 4 weeks
3. H_2 blockers may be useful. Promotility drugs may be indicated
4. Prednisolone or azathioprine may be used if there is no response to dietary trial or H_2 blockers
5. Antibacterial therapy is used for *Helicobacter* infection
6. Surgery may be indicated to correct gastric outflow obstruction

D. The prognosis is good when the underlying cause is identified. Long-term management is usually required

VI. Gastric outflow obstruction
A. Causes include foreign bodies, chronic hypertrophic pyloric gastropathy, congenital pyloric stenosis, pyloric mass, gastric dilatation-volvulus, or extrinsic compression
B. Clinical signs include projectile vomiting of undigested food, abdominal distention, belching, and weight loss
C. Diagnosis
1. Laboratory findings are unremarkable unless profuse vomiting occurs and results in hypokalemia, hyponatremia, hypochloremia, and metabolic alkalosis
2. The finding of a distended stomach filled with food more than 12 hours after eating suggests delayed gastric emptying. Endoscopy may be useful to identify foreign bodies and masses

D. Surgery is the definitive therapy. Administer fluid therapy and gastric promotility drugs if necessary

VII. Gastric motility disorders
A. Possible factors include drugs (e.g., anticholinergic, adrenergic, or narcotic), gastric or abdominal inflammation, metabolic abnormalities (e.g., hypokalemia, endotoxemia, hypothyroidism), neurogenic causes (e.g., dysautonomia), nervous inhibition (stress, pain), or prolonged mechanical obstruction

B. Clinical signs are similar to those of gastric outflow obstruction
C. Abdominal radiograph may suggest delayed gastric emptying as described for gastric outflow obstruction. However, the gastric outflow region appears normal
D. Treat the underlying cause. Feed a diet low in fat and high in digestible carbohydrate. Feed small amounts frequently. A liquid diet may be better tolerated. Use promotility drugs as needed

VIII. Hypertrophic gastropathy is a heterogeneous group of disorders
A. Cause is unknown in most cases. Possible causes include stress in excitable small-breed dogs, chronic irritation from aspirin therapy, or hypergastrinemia
B. Clinical signs include chronic intermittent vomiting, anorexia, weight loss, abdominal distension, hematemesis, and concurrent diarrhea in basenjis. Typically occurs in small-breed dogs with chronic intermittent vomiting
C. Metabolic alkalosis may occur with profuse vomiting and gastric outflow obstruction. Gastrin concentrations may be elevated. Radiography shows delayed gastric emptying. Surgery is required to obtain a full-thickness biopsy
D. Surgical excision may be necessary to relieve outflow obstruction. Promotility drugs may be needed after surgery. Treatment may also include H_2 blockers, sucralfate, or prednisolone if indicated

IX. Gastric neoplasia
A. Adenocarcinoma is most common in dogs, and lymphoma is most common in cats. Leiomyosarcoma and fibrosarcoma are less common
B. Leiomyomas are the second most common gastric tumors in dogs. Benign adenomatous polyps occur infrequently in dogs and cats
C. Clinical signs include progressive vomiting, hematemesis, anorexia, and weight loss. Clinical signs may be absent with benign tumors unless obstruction occurs
D. Contrast radiography and endoscopy are most useful for diagnosis
E. Removal by partial gastrectomy is the treatment of choice, with chemotherapy if indicated. Prognosis is good for benign tumors but poor for adenocarcinoma

X. Gastric dilatation-volvulus (GDV)
A. GDV causes complete obstruction of gastric outflow, which impairs venous return through the vena cava causing hypovolemic and endotoxic shock
B. The cause is unknown. Older large-breed, deep-chested dogs are predisposed. Risk factors include having a first-degree relative affected by GDV, lean body conformation, rapid eating, eating from a raised bowl, eating one meal daily, exercise or stress after a meal, and a fearful temperament
C. Clinical signs include acute onset of abdominal distension, nonproductive retching, salivating, and respiratory distress
D. Physical examination usually reveals tympani on abdominal percussion and findings indicative of hypovolemia or shock. Hypokalemia and metabolic acidosis are often present. Radiography shows overdistension of the stomach with gas, pyloric displacement, and compartmentalization of the stomach on lateral view. Splenomegaly is also seen. Pneumoperitoneum suggests gastric perforation
E. Initial medical management
1. Decompress the stomach, preferably by intubation
2. Administer fluids and treat for shock
3. Control infection and endotoxemia with antibiotics and glucocorticoids
4. Treat cardiac arrhythmias; correct hypokalemia
F. Surgical management is aimed at repositioning of the stomach and spleen, resecting devitalized gastric and splenic tissue, and permanently fixing the stomach to prevent future recurrences of volvulus
G. Prevention involves feeding frequent, small portions of food, and restricting exercise and access to water for 1 hour after eating

XI. Surgery of the stomach. See Chapter 27 for a review of surgical procedures

INTESTINAL DISORDERS

I. Diarrhea overview
A. Acute vs. chronic diarrhea
1. Acute diarrhea has a sudden onset, with duration of 3 weeks or less. Treatment is mainly supportive and nonspecific
2. Chronic diarrhea persists for 4 weeks or longer or has episodic recurrence
B. Small bowel vs. large bowel
1. Small bowel diarrhea is characterized by a large volume of feces with a rancid smell. May be associated with excessive flatulence and weight loss. Steatorrhea may occur in maldigestive or malabsorptive disorders
2. Large bowel diarrhea is characterized by frequent urges to defecate, straining, and small quantities of feces. Hematochezia, mucus, or exudates may be present
C. Diagnostic approach for diarrhea (Table 16-1)
1. History: Consider extraintestinal causes of diarrhea. Review the mode of onset; duration; clinical course; fecal characteristics; correlation with diet, medication, or stressful events; response to treatment; and association with other signs
2. Physical examination: Perform rectal examination, and palpate abdomen. Look for signs of systemic disease
3. Routine laboratory tests (CBC, biochemistry profile) and thyroid profile in cats to exclude hyperthyroidism
4. Fecal examination for parasites, bacteria, blood, and fecal fat
5. Serum folate and cobalamin assays. Serum folate may be decreased in enteropathies that impair absorption in the proximal small intestine, and increased with overproliferation of the normal intestinal flora, or exocrine pancreatic insufficiency (EPI). Serum cobalamin may

Table 16-1 Physical Findings in Intestinal Disease

Physical Finding	Potential Clinical Associations
General Physical Examination	
Dehydration	Diarrheal fluid loss
Depression or weakness	Electrolyte imbalance, severe debilitation
Emaciation or malnutrition	Chronic malabsorption, protein-losing enteropathy
Dull unthrifty hair coat	Malabsorption of fatty acids, protein, and vitamins
Fever	Infection, transmural inflammation, neoplasia
Edema, ascites, pleural effusion	Protein-losing enteropathy
Pallor (anemia)	Gastrointestinal blood loss, anemia of chronic inflammation
Intestinal Palpation	
Masses	Foreign body, neoplasia, granuloma
Thickened loops	Infiltration (inflammation, lymphoma)
"Sausage loop"	Intussusception
Aggregated loops	Linear intestinal foreign body, peritoneal adhesions
Pain	Inflammation, obstruction, ischemia, peritonitis
Gas of fluid distention	Obstruction, ileus, diarrhea
Mesenteric lymphadenopathy	Inflammation, infection, neoplasia
Rectal Palpation	
Masses	Polyp, granuloma, neoplasia
Circumferential narrowing	Stricture, spasm, neoplasia
Coarse mucosal texture	Colitis, neoplasia

From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal clinical Practice,* 3rd ed. St Louis, 2006, Saunders, p. 704.

be decreased in EPI, enteropathies that impair absorption in the distal small intestine, or small intestinal bacterial overgrowth

6. Imaging, including plain radiography, barium radiography, or ultrasonography
7. Endoscopy or laparotomy

D. Nonspecific treatment of diarrhea
 1. Dietary management
 a. Acute diarrhea: Restrict food intake for at least 24 hours and then give bland, low-fat foods (e.g., boiled rice and chicken or low-fat cottage cheese) in small amounts at frequent intervals. Gradually reintroduce the animal's regular diet when the diarrhea has been resolved for 48 hours
 b. Chronic diarrhea: Give three or four meals a day, and use appropriate diets (fiber-supplemented if large bowel diarrhea; novel protein diets with inflammatory bowel disease [IBD]).
 2. Fluid therapy to correct dehydration and electrolyte abnormalities
 3. Antidiarrheal drugs are used short-term to control fluid loss. Loperamide or diphenoxylate are most effective
 4. Corticosteroids are indicated for IBD, and NSAIDs may be used in chronic colitis
 5. Antibiotic should be used only to treat specific bacterial enteropathogens
 6. Fenbendazole therapy for common intestinal nematodes and *Giardia* spp.
 7. Cobalamin therapy in chronic small intestinal disease or exocrine pancreatic insufficiency

II. Dietary diarrhea
 A. Dietary indiscretions include overeating, ingestion of spoiled garbage, and ingestion of abrasive or indigestible foreign material that can traumatize the GI mucosa. Common in dogs
 B. Diagnosis is by review of history
 C. Self-limiting with feeding of a restricted diet and prevention of indiscriminant eating

III. Drug- and toxin-induced diarrhea
 A. Many medications may cause diarrhea (e.g. NSAIDs, digitalis, lactulose, antihelmintics, antibiotics, many antineoplastic drugs). Dexamethasone has been associated with hemorrhagic gastroenterocolitis, especially in dogs with intervertebral disc disease
 B. Many exogenous toxins cause diarrhea (e.g., bacterial enterotoxins causing food poisoning, heavy metals, insecticides)
 C. Diagnosis is based on a review of the history
 D. Diarrhea usually resolves with discontinuation of the medication or dose reduction, and with elimination of the toxin from the body. Give supportive treatment as indicated

IV. Intestinal parasites: Helminths
 A. Ascarids
 1. *Toxocara canis* is the most prevalent intestinal parasites of dogs. *Toxocara cati* occurs in cats
 2. Routes of infection include transplacental (*T. canis*), milk-borne (*T. canis*, *T. cati*), ingestion of infective eggs (all), ingestion of a paratenic host (*T. canis*), or an intermediate host (*T. leonina*)
 3. Clinical signs occur most often in puppies and kittens and may include abdominal discomfort, potbelly, stunted growth, and diarrhea. Intestinal obstruction caused by large masses of worms or severe lung damage due to migration occurs rarely
 4. Diagnose on routine fecal examination
 5. Treat with pyrantel pamoate
 6. Toxocaral visceral larval migrans can occur in humans when larva penetrate the skin
 B. Hookworms
 1. *Ancylostoma caninum*, the most common hookworm in the dog, is a bloodsucker. *Ancylostoma tubaeforme*, the common hookworm in the cat, feeds on tissue. *Ancylostoma braziliense* (southern United States) and *Uncinaria stenocephala* (Canada) are less common in dogs and cats and are only mildly pathogenic

2. Routes of infection include prenatal, milk-borne, ingestion of infective larvae or paratenic hosts, or skin penetration by infective larvae. Eggs are passed in the feces after 2-3 weeks
3. Clinical signs are associated mostly with blood-sucking activity and include melena, bloody diarrhea, pallor, emaciation, and dehydration. Acute blood loss in neonates may lead to death. Chronic blood loss in older animals results in iron deficiency anemia
4. Diagnose on routine fecal flotation
5. Treat with pyrantel pamoate (safest for pups), fenbendazole, or febantel

C. Whipworms
1. *Trichuris vulpis* is common in dogs. The adult nematode attaches to the colonic and cecal mucosa, where it feeds on blood and tissue fluids, thereby causing colitis and typhlitis
2. Infection occurs by ingestion of infective ova, and the life cycle is direct. Ova may remain infectious in the environment for 4 to 5 years
3. Acute, chronic, or intermittent signs of large bowel–type diarrhea occur commonly. Hematochezia may sometimes occur
4. Ova can be identified on fecal flotation. Hyperkalemia and hyponatremia may occur with severe diarrhea
5. Treat with fenbendazole or febantel. Retreat every 2 to 3 months if dogs have access to contaminated ground

D. Strongyloides
1. Found in the southern Gulf States. *Strongyloides stercoralis* resides in the proximal small intestines in dogs. *Strongyloides tumefaciens* resides in the large intestines in cats
2. Infectious larvae are ingested or penetrate the skin, and adult worms develop in the small intestine following migration in the circulation and lung. Larvae are passed in the feces
3. *S. stercoralis* may cause acute hemorrhagic enteritis that may be fatal in pups. *S. tumefaciens* is usually asymptomatic. Colonic nodular proliferations develop in some cats and are associated with chronic diarrhea
4. Ova containing first-stage larvae can be identified in feces by flotation techniques. Free larvae may be identified by direct microscopic examination of fresh feces or by the Baermann technique
5. Treat with fenbendazole, diethylcarbamazine, or pyrantel pamoate

E. Tapeworms
1. *Dipylidium caninum* is the most common tapeworm in dogs and cats. Others include *Taenia pisiformis* in the dog and *Taenia taeniaeformis* in the cat
2. Fleas and lice are intermediate hosts for *D. caninum*. *Taenia* spp. infection occurs by ingestion of cysticercus-infected tissues from intermediate hosts
3. Most infections are asymptomatic. Mild decline in body condition or anal pruritus may occur
4. Diagnosis is made by identification of proglottids in the feces
5. Treat with praziquantel. Control fleas and lice

V. Intestinal parasites: Protozoa

A. Coccidia
1. Primary enteric disease is caused by *Isospora* spp. and *Cryptosporidium*. *Toxoplasma gondii* and *Neospora caninum* cause multisystemic infections
2. Infection usually occurs by ingestion of sporulated oocysts from feces contamination
3. Diarrhea is the characteristic sign. It may vary from soft to fluid and may contain mucus or blood. Vomiting, weight loss, and dehydration may also occur. Most infected animals are asymptomatic. Clinical signs commonly occur in newborns in unsanitary and stressful conditions
4. *Isospora* can be identified in fresh feces. Fecal immunoassay or polymerase chain reaction (PCR) is available for *Cryptosporidium*
5. Treat *Isospora* with sulfadimethoxine, trimethoprim-sulfa, or furazolidone. Treat *Cryptosporidium* with azithromycin. *Cryptosporidium* is zoonotic

B. *Giardia*
1. Infective cysts pass through feces into the environment, and infection occurs by ingestion of contaminated food or water
2. Clinical signs result from intestinal malabsorption and include large volume of feces, steatorrhea, and weight loss. Diarrhea may be acute or chronic, intermittent, or continuous. Most infected animals are asymptomatic
3. Diagnosis is by microscopic examination of feces or a fecal immunoassay for antigen
4. Treat with fenbendazole. *Giardia* may be resistant to metronidazole. Furazolidone is effective in cats. Clean the environment, and bathe animals

C. *Tritrichomonas foetus* in cats
1. *T. foetus* causes mild to severe lymphoplasmacytic colitis and chronic large intestinal diarrhea in young cats
2. Clinical signs consist of diarrhea that may wax and wane in an otherwise healthy animal
3. Fecal PCR assay is the most accurate method of diagnosis. Trophozoites are observed in fresh fecal smears in a low percentage of cases
4. Treat with antibiotics, treat concurrent infections, and improve environmental conditions

D. *Entamoeba*
1. *E. histolytica* infection occurs by drinking contaminated water
2. Clinical signs include bloody-mucoid diarrhea
3. Diagnosis can be made by detecting trophozoites in fecal smears or cysts in zinc sulfate flotation
4. Treat with metronidazole

E. *Balantidium*
1. *B. coli* rarely causes chronic ulcerative colitis in dogs

2. Diagnosis is made by identification of trophozoites in saline fecal suspensions
3. Treat with metronidazole

VI. Viral infections
- A. Canine parvovirus, coronavirus, and rotavirus cause viral enteritis and diarrhea in dogs. Canine parvovirus is acute, severe, highly contagious enteritis
- B. Coronavirus and rotavirus are less prevalent and cause mild clinical signs except in neonates
- C. Canine distemper virus also causes diarrhea

VII. Bacterial infections
- A. *Salmonella*
 1. Transmitted by the fecal-oral route, mainly through ingestion of contaminated food or water. Migratory birds have been reported a source of infection in cats, raw-food diets in dogs
 2. Clinical signs of enterocolitis include acute watery or mucoid diarrhea, containing blood in severe cases, vomiting, tenesmus, and fever. Some animals may have chronic or intermittent diarrhea, and many are asymptomatic carriers
 3. Diagnosis is by isolation of the bacteria from fecal or blood samples
 4. Treat with antibiotics (enrofloxacin or trimethoprim-sulfa), and correct fluid deficits. Mortality is high in neonates
 5. Salmonellosis is a zoonotic disease
- B. *Campylobacter*
 1. Most infected dogs are clinically normal carriers. Exposure is high with overcrowding and poor sanitation
 2. Clinical signs include watery-mucoid diarrhea. Hematochezia, vomiting, and tenesmus may occur. Fever is usually mild or absent. Some animals may have chronic or intermittent diarrhea
 3. Diagnosis is by isolation of *Campylobacter* from feces
 4. Treat with erythromycin, enrofloxacin, or azithromycin. Carrier state may persist
- C. *Clostridium perfringens*
 1. These bacteria normally reside in the bowel in the vegetative form but can release their toxin (CPE) during sporulation endogenously within the bowel or exogenously in contaminated food
 2. Clinical signs include watery to soft diarrhea, with hematochezia or tenesmus. *C. perfringens* has been associated with acute hemorrhagic gastroenteritis with severe hemoconcentration in dogs
 3. A definite diagnostic test is not available. Fecal cultures are not useful because *C. perfringens* is a part of the normal flora. Fecal assays for CPE are available
 4. Treat with ampicillin, amoxicillin-clavulonate, tylosin, or clindamycin. Metronidazole seems to work less consistently. Long-term treatment may be required in chronic or recurrent cases. Fiber-containing diet or supplementation with psyllium may help to reduce bacterial proliferation and sporulation
- D. *Clostridium difficile*
 1. *C. difficile* and its toxin may be found in normal dogs and cats and also in animals with mild diarrhea or acute hemorrhagic diarrhea. Pseudomembranous colitis as seen in people is not seen in dogs and cats
 2. Fecal cultures are not useful because *C. difficile* is a part of the normal flora. Fecal assays for toxins A and B are available
 3. Treatment with metronidazole is recommended

VIII. Fungal infections
- A. Intestinal pythiosis and zygomycosis
 1. *Pythium insidiosum* and *Zygomycetes* can invade the digestive tract, causing granulomatous tissue reactions
 2. Pythiosis is most common in young large-breed dogs in the southern Gulf States. It is rare in cats
 3. Clinical signs include chronic intractable diarrhea (may be bloody) and vomiting, depression, and progressive weight loss
 4. Confirmation of diagnosis requires histologic identification in biopsies
 5. Treatment involves radical surgical excision of the affected segments. A combination of amphotericin B, itraconazole, and terbinafine may be successful. Prognosis is guarded to poor
- B. Histoplasmosis is a multisystemic infection with intestinal involvement caused by *Histoplasma capsulatum*

IX. Intestinal protothecosis
- A. Caused by algae that may rarely colonize the intestinal tract of dogs and cause severe necrotizing or ulcerating enterocolitis
- B. Clinical signs include large bowel diarrhea with hematochezia. Additional signs are related to invasion of other organs (visceral organs, eye, central nervous system [CNS])
- C. Identify organisms in feces, cytology preparations, and biopsies
- D. Treat with a combination of amphotericin B and itraconazole

X. Chronic IBD
- A. Lymphocytic-plasmacytic IBD
 1. This is the most common form of IBD in dogs and cats. Factors that may play a role include mucosal hypersensitivity to antigens, and genetic factors (basenji, German shepherd dog, soft-coated wheaten terrier, and shar-pei)
 2. Clinical signs include vomiting, diarrhea, and weight loss. Protein-losing enteropathy may be present. Signs may be intermittent and last for months to years
 3. IBD is a diagnosis of exclusion of all known causes of lymphocytic-plasmacytic inflammation of the intestinal tract
 a. Abnormalities on endoscopic examination include mucosal erythema, petechiae erosions, or ulcers, increased mucus, friability, or granularity, decreased visibility of the

colonic submucosal vessels, thickened folds, or decreased distensibility. Normal endoscopic appearance does not rule out IBD
b. Mucosal histopathology shows diffuse infiltration of the lamina propria with mature lymphocytes and plasma cells in association with mucosal damage
c. Evaluate for dietary hypersensitivity
4. Treatment
a. Dietary therapy with a novel protein source, or fiber supplementation may be helpful
b. Medical therapy
(1) Oral prednisolone is the most consistently effective medical therapy. Metronidazole is also often used for long-term therapy
(2) Other agents that may be indicated include cobalamin, azathioprine, chlorambucil, cyclosporine, or motility-modifying antidiarrheal drugs
5. Persistence or recurrence of IBD is likely despite therapy

B. Eosinophilic gastroenteritis
1. An uncommon form of IBD, characterized by infiltration of the GI tract with mature eosinophils. Food allergy and parasitism are possible causes, but most cases are idiopathic. Feline hypereosinophilic syndrome is characterized by multiorgan severe eosinophilic infiltration
2. Clinical signs include chronic vomiting, and small or large bowel diarrhea. Protein-losing enteropathy may be present, and granulomas can cause intestinal obstruction
3. Diagnosis is based on demonstration of eosinophilic inflammation in intestinal biopsies
4. Treatment includes fenbendazole to exclude parasites and a feeding trial to exclude food allergy. Oral prednisolone is the most effective treatment, and response to treatment is rapid

C. Regional granulomatous enterocolitis
1. An uncommon form of IBD characterized by transmural granulomatous inflammation resulting in a mass-like thickening of the bowel wall. The ileocolic junction is most often involved. The lesion may contain many eosinophils
2. Clinical signs include chronic large bowel diarrhea containing mucus and fresh blood and sometimes tenesmus and abdominal pain
3. Diagnosis requires biopsy to detect fungi and acid-fast organisms. Eosinophilia, neutrophilia, monocytosis, and panhypoproteinemia may be present
4. Treat as for lymphocytic-plasmacytic IBD. Surgical excision may be required

D. Histiocytic ulcerative colitis
1. Chronic idiopathic IBD of young boxer dogs characterized by infiltration of the colon by distinctive periodic acid-Schiff (PAS)-positive histiocytes
2. Clinical signs include severe, bloody-mucoid large bowel diarrhea in young boxers
3. Diagnosis is based on breed and presence of PAS-positive histiocytes in a biopsy
4. Treat with enrofloxacin with metronidazole. Feed a highly digestible diet

E. Neutrophilic (suppurative) enterocolitis
1. Cause is unknown
2. Clinical signs consist of large bowel diarrhea that can be either acute or chronic
3. Diagnosis is based on biopsy
4. Treat with antibiotics, antiinflammatory, and immunosuppressive agents

XI. Fiber-responsive diarrhea
A. Chronic, noninflammatory, mucoid large bowel diarrhea
B. Clinical signs include intermittent mucoid diarrhea (without hematochezia). Working dogs and excitable dogs are predisposed
C. Diagnosis is based on exclusion of known causes of colonic disease (e.g., dietary, infectious, parasitic, IBD), including a normal colonoscopic biopsy
D. Feed a digestible diet with fiber supplementation (psyllium). Consider motility-modifying antidiarrheal drugs if dietary modification is unsuccessful

XII. Protein-losing enteropathy
A. A variety of intestinal diseases associated with accelerated loss of plasma proteins into the gut either caused by impaired lymphatic drainage or mucosal injury
B. Most frequently occurs with chronic enteropathies (e.g., lymphangiectasia, IBD, histoplasmosis, lymphoma)
C. Clinical signs include severe hypoalbuminemia (subcutaneous edema, ascites, hydrothorax) and chronic intermittent or persistent diarrhea
D. Diagnosis
1. Typical laboratory findings in intestinal lymphangiectasia include hypoalbuminemia, hypoglobulinemia, lymphopenia, hypocholesterolemia, and hypocalcemia. Perform liver function tests and urine protein determination to exclude other causes of hypoalbuminemia
2. Radiography and ultrasonography may detect abdominal and thoracic effusions
3. Definitive diagnosis requires identification of the characteristic lymphatic lesions in biopsies. Full-thickness biopsies may be required for the diagnosis
E. Treatment is similar to that of lymphocytic-plasmacytic IBD. Dietary fat restriction is warranted. Response to therapy is unpredictable

XIII. Villous atrophy is associated with intestinal malabsorption and chronic diarrhea
A. Causes
1. Primary causes include gluten-sensitive enteropathy of Irish setters and idiopathic canine villous atrophy in German shepherds
2. Secondary causes include diffuse infiltrative intestinal diseases (e.g., chronic IBD, lymphoma), and enteric infections (e.g., coronavirus, *Giardia*, bacterial overgrowth)
B. Clinical signs include small bowel diarrhea and weight loss

C. Diagnosis is by histologic documentation of villous atrophy in jejunal biopsies
D. Treatment
1. For gluten-sensitive enteropathy, eliminate gluten-containing cereal grains (wheat, barley, and rye) from the diet for life. Breeding of affected animals is discouraged
2. For idiopathic villous atrophy, dietary management with gluten-restricted diet is sometimes beneficial. Folate, cobalamin, antibiotics, or prednisolone may be beneficial
E. Prognosis is guarded. Clinical signs often persist despite treatment

XIV. Small intestinal bacterial overgrowth
A. Causes
1. An overproliferation of microflora within the proximal small intestine that results in malabsorption and diarrhea
2. May develop secondary to other disorders (e.g., intestinal obstruction, dysfunction of the ileocolic junction, motility disorders, hyposecretion of gastric acid, exocrine pancreatic insufficiency)
3. Immunoglobulin A deficiency may explain the breed predilection in German shepherds, basenjis, and shar-peis
B. Clinical signs consist of chronic watery diarrhea and steatorrhea. Blood or mucus is usually absent
C. Diagnosis requires quantitative aerobic and anaerobic cultures of duodenal juice taken by endoscopy, intestinal intubation, or laparotomy after an 18-hour fast. This may be impractical. Indirect evidence to support the diagnosis includes response to antibiotics, elevated serum folate and decreased serum cobalamin, presence of predisposing disorder, and minimal changes in intestinal biopsies
D. Treat with tetracycline, tylosin, and metronidazole for 10 to 14 days. Some animals need continuous treatment

XV. Intestinal neoplasia
A. Benign tumors include adenomatous polyps, adenomas, and leiomyomas
B. Malignant tumors include adenocarcinoma and lymphoma most commonly. Less common malignancies include carcinoid tumors, leiomyosarcoma, fibrosarcoma, mastocytoma, hemangiosarcoma, and anaplastic sarcoma
C. Clinical signs are initially vague and progress to vomiting and diarrhea. Signs may vary with location of neoplasia
D. Definitive diagnosis requires biopsy. Abdominal radiography or ultrasonography may detect intestinal masses
E. Surgical resection is the treatment of choice, with appropriate adjunct therapy

XVI. Intestinal obstruction
A. Cause can be intraluminal, intramural, or extramural
B. Pathophysiology
1. Proximal vs. distal obstruction
a. The more proximal and complete the obstruction, the more acute and severe the signs
b. Gastric outlet obstruction causes hypochloremic metabolic alkalosis. More distant obstructions cause varying degrees of metabolic acidosis
2. Simple vs. strangulated obstruction: Simple obstructions occlude the lumen; strangulated obstructions cause vascular compromise of the obstructed bowel segment
C. Clinical signs depend on the location, completeness, duration of the obstruction, and presence of strangulation. Signs include acute onset of vomiting, anorexia, depression, abdominal distension or pain, diarrhea, melena, hematochezia, and shock
D. Diagnosis
1. Abdominal palpation may identify foreign bodies, intussusceptions (“sausage loop”), or distended bowel loops
2. Radiographic findings include gas or fluid distention of the bowel, retention of contrast material, and luminal filling defects
E. Treatment involves surgical removal of the obstruction, management of complications, and supportive medical treatment

CONSTIPATION AND ANORECTAL DISEASES

I. Constipation
A. Cause
1. Ingestion of foreign material (e.g., hair in cats, bones in dogs)
2. Environmental conditions (e.g., unfamiliar surroundings) may cause inhibition of defecation
3. Painful defecation resulting from anorectal disease (e.g., anal sacculitis) or orthopedic disorders that limit positioning may lead to inhibition of defecation
4. Rectocolonic obstruction may be caused by intraluminal causes (e.g., foreign body, perineal hernia) or external compression (e.g., prostatic enlargement, pelvic fractures)
5. Neuromuscular disease may interfere with colonic innervations or smooth muscle function or with positioning for defecation. Examples include intervertebral disc disease at the lumbosacral region, dysautonomia, and hypothyroidism
6. Fluid and electrolyte disorders: Dehydration causes feces to become dry and hard; hypokalemia and hypercalcemia can impair colonic smooth muscle function
7. Drug-related (e.g., anticholinergics, opiates, loperamide, antihistamines, barium sulfate)
B. Clinical signs include reduced or absent defecation, dyschezia, abdominal discomfort, and paradoxical diarrhea (fluids secreted by the irritated mucosa may pass around the retained feces). Prolonged constipation may lead to anorexia, vomiting, and dehydration
C. Diagnosis
1. Review history to identify an underlying cause
2. Physical examination, including rectal examination and abdominal palpation

3. Laboratory evaluation (CBC, biochemical profile, and urinalysis) may identify underlying systemic disease, dehydration, or electrolyte disorders
4. Abdominal radiography can confirm the diagnosis; evaluate the extent of colonic impaction; and identify megacolon, radiopaque foreign bodies, pelvic or spinal lesions, and prostatic enlargement. Barium enema contrast radiography may identify intraluminal obstruction (Figure 16-3)
5. Abdominal ultrasonography may be useful to evaluate the prostate and pelvic canal area
6. Other tests may be indicated to evaluate thyroid function and neuromuscular disorders (e.g., myelography, magnetic resonance imaging, electromyography, and nerve conduction studies)

D. Treatment overview
1. Control any identified predisposing factor
2. Simple constipation without systemic signs can be managed using rectal suppositories or oral laxatives combined with dietary modification and promotion of water intake. Severe constipation may initially require evacuation of impacted feces from the colon with correction of dehydration and electrolyte imbalances
3. Prevent recurrence using dietary modification, laxatives, and promotility agents as needed
4. Surgical management is required for obstructing neoplasms, strictures, and pelvic malformations. Subtotal colectomy is often required to manage advanced megacolon

E. Initial relief of constipation
1. Rectal suppositories of docusate (emollient), glycerin (lubricant), or bisacodyl (stimulant) may be used to promote defecation in patients with mild constipation
2. Enema therapy is used to soften hard, impacted feces. Administer the warmed enema solution through a rubber catheter or feeding tube. Enema solutions include tap water, isotonic saline, lactulose (osmotic), docusate (emollient), or mineral oil (lubricant). Phosphate enemas may cause life-threatening hyperphosphatemia in cats and small dogs
3. Manual extraction of impacted feces under general anesthesia may be necessary in severe cases. Use colonic irrigation with warm saline to soften the feces, extract the feces by transabdominal manipulation into the distal rectum for digital or forceps removal

F. Oral laxative therapy
1. High-fiber bulk-forming laxatives are available as commercial high-fiber diets or fiber supplements (e.g., wheat bran, psyllium)
2. Lubricant laxatives: Flavored petrolatum is preferred. Mineral oil may lead to inhalation lipid pneumonia and should not be given orally
3. Emollient laxatives: Docusate is a mild laxative, and its efficacy depends on patient hydration
4. Osmotic laxatives: Lactulose is the most clinically useful and effective. It is safe for long-term use
5. Stimulant laxatives: Bisacodyl is the most effective, but long-term use may damage the myenteric plexus. Contraindicated in the presence of an obstructive lesion
6. Promotility drugs are contraindicated in the presence of an obstructive lesion. Cisapride is the most effective

II. Megacolon in cats
A. Most cases are idiopathic. Obstructive rectocolonic disorder is found in up to 25% of the cases (perineal hernia, anorectal stricture, or neoplasia). Neurologic dysfunction may account for up to 5% of the cases (Manx cat deformity, dysautonomia)
B. Clinical signs occur mostly in middle-aged and older cats. Males are predisposed. Signs consist of progressive constipation and obstipation
C. Diagnosis is based on finding severe colonic dilatation and impaction with feces on abdominal palpation and abdominal radiography
D. Treat medically, including evacuation of feces, lactulose, and cisapride. Most cats eventually require subtotal colectomy

III. Proctitis
A. Usually associated with colitis
B. Clinical signs may include tenesmus, diarrhea, and hematochezia

IV. Anorectal prolapse
A. Occurs most frequently in puppies and kittens with persistent straining to defecate because of endoparasitism. Anal sphincter incompetence in Manx cats may be a predisposing factor
B. A partial prolapse appears as a red, swollen, doughnut-shaped ring of prolapsed mucosa. Complete prolapse appears as an edematous, cylindrical-shaped mass
C. Diagnosis based on physical examination. Differentiate from intussusception
D. Treat underlying disorders, and manually reduce the prolapse. Surgical treatment may be required

V. Perineal hernia
A. Weakened perineal musculature fails to support the rectal wall, resulting in persistent rectal distention. Occurs mostly in aged, intact male dogs

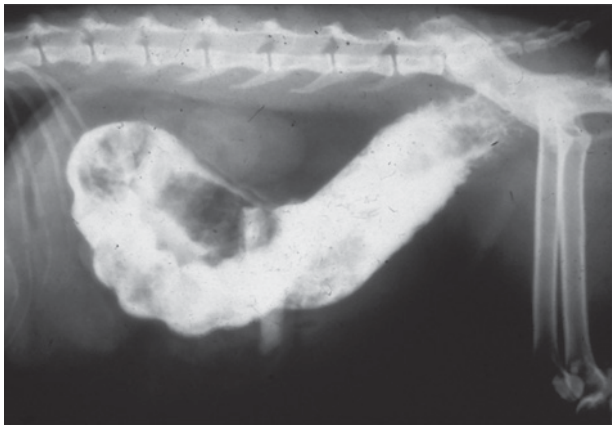


Figure 16-3 Barium enema in a 12-year-old cat with idiopathic constipation and megacolon. (From Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

B. Pathogenesis is unknown. Predisposing factors may include persistent straining, neurogenic atrophy of the muscles, and male hormones. May be a complication of megacolon in cats
C. Clinical signs include perineal swelling that may be unilateral (usually right-sided) or bilateral
D. Diagnosis is based on palpation
E. Laxative therapy and stool softening may be sufficient in mild cases. Castration of male dogs may prevent progression of the disorder. Corrective perineal herniorrhaphy and castration are required in most cases

VI. Anorectal foreign bodies and fecaliths
A. Ingested foreign bodies (e.g., bones, sticks, needles) may become lodged within the rectum or at the anal sphincter
B. Clinical signs include dyschezia and tenesmus
C. Diagnosis is usually confirmed by rectal examination
D. Most foreign bodies and fecaliths may be removed by rectal palpation

VII. Anorectal stricture (stenosis)
A. Strictures may result from trauma caused by foreign body or during treatment of obstipation, anorectal surgery, chronic inflammation (anal sac, perineal fistula, proctitis), or adenocarcinoma
B. Clinical signs include dyschezia, tenesmus, hematochezia, and secondary constipation
C. Diagnosis is made by digital rectal palpation, proctoscopy, or barium enema contrast radiography
D. Treat conservatively in most cases. Balloon dilatation may be successful

VIII. Anal spasm
A. Idiopathic spasm of the anal sphincter when the animal attempts to defecate. Defensive contraction of the sphincter in response to painful defecation may play a role
B. Clinical signs include pain on attempts to defecate and anxiety
C. Occurs most frequently in German shepherd dogs, and digital palpation of the rectum is painful. Exclude other causes of painful defecation
D. Treat conservatively. Resection of the pudendal nerve may be required

IX. Anal and rectal atresia
A. Atresia ani and rectal atresia are congenital malformations
B. Clinical signs include inability to defecate resulting in abdominal distention, tenesmus, systemic deterioration, and death
C. Diagnosis is based on history and physical examination
D. Treatment requires surgical correction. Prognosis is guarded for rectal atresia

X. Rectovaginal fistula
A. A rare congenital malformation of females characterized by passage of fecal material through the vaginal opening. It is accompanied by atresia ani in many cases
B. The defect can be surgically corrected, but the prognosis is guarded

XI. Anal sac disease
A. Impaction is usually bilateral. The anal sac is distended, mildly painful, and not readily expressed. Anal sacculitis may be unilateral or bilateral and associated with moderate to severe pain and purulent contents. Anal sac abscesses are usually unilateral and are characterized by marked distension of the sac with pus, erythema of the overlying skin, and fever
B. Clinical signs include scooting the hind end on the floor, tenesmus, and licking and biting the anal area
C. Diagnosis is based on examination of the anal sacs
D. Manually evacuate, irrigate with povidone-iodine solution, and treat with systemic antibiotics based on culture and sensitivity. A high-fiber diet may help to prevent recurrence. Anal sacculectomy may be required

XII. Perianal fistula
A. Perianal fistulas are deep ulcerating tracts in the perianal tissues. They occur most frequently in German shepherd dogs and Irish setters
B. Clinical signs commonly include dyschezia, tenesmus, and severe anal discomfort. Hematochezia, constipation, fecal incontinence, and purulent perianal discharge may be present
C. Diagnosis is established by examination of the perineal area. The anal sacs may be involved
D. Medical therapy with hair removal and cleansing, systemic antibiotic therapy, and immunosuppressive therapy is often effective. Surgical therapy is indicated in refractory cases
E. Prognosis is better when treatment is early. Fecal incontinence and anal stenosis are complications of extensive disease or surgical procedure

XIII. Pseudocoprostasis
A. Occurs when the anal opening is obstructed by surrounding hair. Diarrhea and obesity may be predisposing factors
B. Clinical signs include constipation, restlessness, and biting the anal region. Dermatitis may occur
C. Diagnosis is established by visual examination
D. Treatment includes clipping of the hair, cleansing, and antibiotic treatment when needed

XIV. Rectal, anal, and perianal tumors
A. Benign rectal polyps
1. Common in middle-aged and older dogs. They are usually solitary, focal, pedunculated, or sessile masses
2. Clinical signs include hematochezia, dyschezia, tenesmus, or excessive licking of the anal region
3. Detect with rectal palpation; biopsy is required for definitive diagnosis
4. Surgical excision is the treatment of choice
B. Perianal gland adenoma
1. Androgen-dependent tumors that occur most often in older, intact male dogs
2. Usually appear as small, firm, well-circumscribed nodules in the skin surrounding the anus
3. Clinical signs may be absent or may include scooting and licking at the area. Ulceration may occur
4. The treatment of choice is surgical excision and adjunctive castration

C. Perianal gland adenocarcinoma
 1. Occur most often in aged female dogs. Locally invasive and eventually metastasize. Their appearance can be confused with a perianal fistula or a ruptured anal sac
 2. Diagnosis requires biopsy. Perform thoracic and abdominal radiography and abdominal ultrasonography to evaluate for metastases
 3. Early excision can be effective, but if metastases have occurred, the prognosis is poor

D. Apocrine gland adenocarcinoma
 1. Occurs in middle-aged and older dogs. Metastasize to sublumbar lymph nodes and distant sites
 2. Often an incidental finding. Clinical signs may include perianal irritation, constipation, or polyuria and polydipsia secondary to hypercalcemia
 3. Surgical excision is the treatment of choice

LIVER AND BILIARY TRACT DISORDERS

I. Diagnostic overview
 A. Diagnostic strategy
 1. Clinical signs and laboratory abnormalities are diverse because of the multiple functions of the liver
 2. Diagnosis includes identification of the presence of liver disease, characterization of liver function, and determination of etiologic or histologic diagnosis
 3. Long-term prognosis of acute hepatic failure may be favorable because of hepatic regeneration, whereas chronic hepatic disorders are usually accompanied by irreversible changes and unfavorable prognosis
 B. Clinical signs
 1. Nonspecific signs such as anorexia and vomiting are common. Small bowel diarrhea is less common. Hematemesis suggests gastroduodenal ulceration. Weight loss and stunted growth suggest a chronic disorder
 2. Polyuria and polydipsia may be present as a result of psychogenic polydipsia, hypercortisolism, and renal concentrating defects
 3. Signs of abnormal bilirubin excretion include pigmented urine resulting from bilirubinuria and jaundice. Acholic feces occur in severe cholestasis
 4. Coagulopathies occur due to decreased clotting factors synthesis by the hepatocytes, vitamin K deficiency, and disseminated intravascular coagulation (DIC)
 5. Hepatic encephalopathy
 a. A metabolic encephalopathy that occurs due to severe liver disease or portosystemic shunting of blood. Encephalopathic toxins, such as ammonia, mercaptans, short-chain fatty acids, γ-aminobutyric acid (GABA), and endogenous benzodiazepines, are produced in the colon and are normally detoxified by the liver. Severe liver disease or portosystemic shunting result in increased systemic concentration of these toxins resulting in clinical signs
 b. Clinical signs wax and wane, are interspersed with normal periods, and may exacerbate after eating a high protein meal. Signs include depression, hypersalivation, behavioral changes, altered consciousness, seizures, and coma
 6. Ascites is common in severe chronic liver disease due to hypoalbuminemia, portal hypertension, and sodium and water retention. Bile peritonitis due to biliary tract rupture may cause ascites
 C. Signalment and history
 1. Specific liver diseases have breed predilections
 2. Chronic hepatic disease may be associated with recent onset of clinical signs due to the large functional reserves of the liver
 D. Physical examination
 1. Jaundice of the sclera, mucous membranes, and skin is clinically detectable with serum bilirubin concentrations over 2.5 to 3.0 mg/dL. May initially be detected on the palatine mucosa in cats
 2. Abdominal palpation may reveal hepatomegaly, pain, or abdominal effusion
 3. Neurologic examination may be normal or suggestive of diffuse cerebral disease
 4. Rectal examination may reveal the presence of melena or acholic feces
 E. Laboratory evaluation
 1. CBC may reveal mild to moderate anemia from blood loss or chronic disease. Erythrocytic microcytosis is common with portosystemic shunts (PSSs) as a result of abnormal iron metabolism. Target cells, acanthocytes, and elliptocytes may occur due to altered red blood cells or membranes
 2. Urinalysis may show isosthenuria or hyposthenuria. Bilirubinuria precedes hyperbilirubinemia and jaundice. Trace bilirubinuria may be found in the urine of normal dogs (especially males). Any bilirubinuria is abnormal in cats. Ammonium biurate crystals are commonly detected with PSSs
 3. Serum biochemistry profile: Refer to Chapter 1 for a review of liver enzymes and liver function tests
 F. Hemostasis evaluation: Refer to Chapter 17 for a review of coagulation tests
 1. Coagulation tests are frequently abnormal; however, clinical evidence of bleeding is uncommon. Increased bleeding can occur from failure of hepatocytes to synthesize clotting factors. The PIVKA (proteins induced by vitamin K absence) clotting time is a more sensitive test than prothrombin time (PT), activated partial thromboplastin time (APTT), and activated coagulation time (ACT)
 2. Thrombocytopenia and platelet dysfunction may be present
 G. Abdominal fluid analysis
 1. In liver disease and hypoalbuminemia, the ascitic fluid is usually a transudate

2. In post-sinusoidal hepatic disorders, the fluid is higher in protein (modified transudate greater than 2.5 g/dL)
3. In rupture of the biliary tract, the abdominal fluid may appear yellow or green, has a bilirubin concentration higher than serum, and shows mixed inflammation on cytology

H. Diagnostic imaging
1. Survey radiographs are useful to evaluate changes in liver size and the presence of choleliths, abscesses, and abdominal fluid
2. Ultrasonography is useful to detect focal parenchymal abnormalities and to evaluate of the biliary tract and vascular disorders. However, a normal ultrasonographic appearance of the liver does not eliminate the possibility of significant hepatic pathology
3. Angiography is used to diagnose vascular disorders such as PSSs

I. Liver cytology
1. Fine needle aspiration of the liver is easy and relatively safe to perform. However, its diagnostic accuracy is controversial (lack of correlation with histopathology in up to 50%)
2. Cytology is most useful in diffuse hepatic pathologies such as feline hepatic lipidosis, diffuse neoplasia, or infections (histoplasmosis)

J. Liver biopsy
1. Often required for the diagnosis of the nature of liver disease, differentiation between acute and chronic disorders, and assessments of response to therapy
2. Perform a hemostatic screen before biopsy is done, and monitor for bleeding
3. Selection of biopsy method depends on liver size, presence of coagulopathy, diffuse vs. focal lesions, presence of other abdominal abnormalities, and general patient condition. Methods include ultrasound-guided needle, laparoscopy, and laparotomy. Fresh liver tissue should be submitted for bacterial and fungal culture if indicated

II. Principles of treatment for liver disease

A. Objectives are to identify and eliminate the inciting or predisposing causes, if possible, and to prevent or manage complications of liver failure

B. Avoid drugs that are primarily inactivated or excreted by the liver, are potentially toxic to the liver, or may worsen signs of liver failure

C. Supportive therapy for liver disease
1. Restore hepatic blood flow. The composition of fluids depends on the presence of electrolyte or acid base abnormalities, or hypoglycemia. Avoid alkalization which can exacerbate hepatic encephalopathy
2. Give nutritional support. Avoid high-protein diets which can exacerbate hepatic encephalopathy. Use gastrostomy tube when indicated

D. Control complications
1. Hepatic encephalopathy
a. Give antibiotics (e.g., neomycin, amoxicillin, or metronidazole) to decrease the urease-producing bacterial population in the colon
b. Lactulose acts as a cathartic and colonic acidifier and thereby decreases ammonia absorption
c. Detect and control GI bleeding, which may provide protein. Use fresh rather than stored blood, which may contain substantial amounts of ammonia
2. Ascites and edema
a. Usually associated with hypoalbuminemia, portal hypertension, and renal retention of sodium and water
b. Restrict dietary sodium; use diuretics. Consider plasma transfusion or colloid administration in hypoproteinemic animals. Avoid abdominocentesis if possible
3. Coagulopathy and anemia. Administer parenteral vitamin K_1 when deficiency is present. Treat DIC
4. GI ulceration can be due to gastric acid hypersecretion or portal hypertension. Manage with sucralfate and H_2 blocker (famotidine and nizatidine are preferable to cimetidine and ranitidine because they do not inhibit hepatic microsomal enzymes)
5. Infection and endotoxemia are managed with systemic antibiotics. Penicillins, cephalosporins, or aminoglycosides are good choices as they are excreted primarily by the kidney

E. Hepatoprotectants
1. Variable group of compounds that may protect the liver include S-adenosylmethionine (SAMe), acetylcysteine, milk thistle (Silybin), ursodiol, L-carnitine, zinc, vitamins E and C
2. There is a lack of safety and efficacy data for many of the nutraceuticals in this group. However, they may have potential therapeutic benefits

III. Acute hepatic failure

A. Occurs when a sudden severe insult to the liver compromises at least 70% to 80% of functional hepatic tissue. In many cases, a specific cause cannot be identified. Potential causes include toxin-induced injury (chemical, biologic, pesticides, heavy metals), drug-induced (acetaminophen, tetracycline, stanozolol, phenobarbital), idiosyncratic hepatotoxins (halothane, carprofen, mebendazole, sulfonamides, methimazole), infectious agents, hemolytic anemia, anesthesia, acute pancreatitis, extrahepatic bacterial infections with septicemia

B. Clinical signs of acute hepatic failure are often nonspecific and reflect general hepatic dysfunction. Cranial abdominal pain may be caused by swelling and stretching of the liver capsule

C. Attempt to identify the underlying cause, and, when jaundice occurs, consider extrahepatic biliary tract disorders. Increased ALT activity is the most consistent finding as diffuse hepatic necrosis is the most common lesion. Increased ALP activity may also occur. Abnormalities in liver function tests may be present. Hypoalbuminemia usually suggests chronic rather than acute disease. Liver biopsy shows diffuse hepatic necrosis in most cases

D. Supportive therapy is most important. Prevent or control complications. Institute specific treatment when possible

IV. Infectious and parasitic hepatic disease
 A. Infectious causes of liver disease include infectious canine hepatitis, leptospirosis, ehrlichiosis, rickettsial diseases, toxoplasmosis, systemic mycoses, and feline infectious peritonitis (FIP)
 B. Hepatic abscess is uncommon in dogs and cats
 1. Potential sources include hematogenous spread, intestinal bacteria (via portal blood or bile ducts), penetrating wounds, and extension from local suppurative diseases. Umbilical infections are the most common cause in puppies and kittens
 2. Clinical signs are attributed to sepsis, inflammation, and liver dysfunction
 3. Neutrophilia with left shift, thrombocytopenia, increased ALT and ALP, hyperbilirubinemia, hypoglycemia, and hyperglobulinemia may be present, along with septic suppurative abdominal effusion
 4. Surgical excision may be required. Treat with broad-spectrum antibiotics. Mortality rate is high
 C. Liver fluke infection is uncommon in cats and rare in dogs
 1. *Platynosomum concinnum* is the most important in cats and is found in tropical and subtropical areas. Other liver flukes have been identified in cats including *Amphimerus pseudofelineus*. The life cycle requires two intermediate hosts; the first is a snail, and the second may be a skink, lizard, Bufo toad, or fish
 2. Cats are usually asymptomatic. Clinical signs (anorexia, weight loss, diarrhea, vomiting, jaundice, hepatomegaly, abdominal distension) may occur if cholangitis or bile duct obstruction occurs
 3. Eggs may be detected in feces or on bile cytology
 4. Treat with praziquantel or fenbendazole

V. Feline hepatic lipidosis is the most common liver disease in cats
 A. Causes
 1. Excessive accumulation of triglyceride in the liver may result from nutritional, metabolic, hormonal (diabetes mellitus [DM]), toxic (tetracycline, stanozolol), and hypoxic liver injury
 2. The term *idiopathic hepatic lipidosis* is used when no underlying disease is identified. It is associated with persistent (i.e., longer than 2 weeks) anorexia and rapid weight loss (usually in overweight cats), sometimes triggered by a stressful event
 3. The exact mechanism is unknown, but cats seem to be predisposed because of higher nutritional requirements for protein and essential nutrients and alterations of fat metabolism in obese and systemically ill cats
 B. Clinical signs suggest hepatic disease. Additional signs may occur if underlying disease is present. Prolonged anorexia is the most consistent sign. Pronounced weight loss in previously obese cats is common. Signs of hepatic encephalopathy are uncommon. Overt bleeding occurs in 20% of cases. Middle-aged to older cats are most commonly affected
 C. Diagnosis
 1. History may reveal precipitating causes, and physical examination reveals hepatomegaly, jaundice, and muscle wasting. Cervical ventroflexion may occur
 2. Hematologic findings are nonspecific (nonregenerative anemia and stress leukogram). Increases in liver enzymes precede increases in total bilirubin and bile acids. Serum ALP activity is higher compared to other hepatic diseases and is associated with normal to mildly increased GGT activity (unlike other hepatic diseases in cats). Coagulation tests are commonly abnormal
 3. The liver is normal to increased in size. Liver biopsy is not routinely performed. Fine-needle aspirate may show foamy, vacuolated hepatocytes
 D. Treatment
 1. For initial fluid therapy, use balanced electrolyte solution supplemented with potassium chloride. Evaluate serum magnesium if hypokalemia persists. Avoid dextrose supplementation unless hypoglycemia is documented (glucose may promote hepatic lipid accumulation). Avoid lactated Ringer's solution (hepatic lactate metabolism may be impaired). Correct hypophosphatemia. Administer vitamin K_1 if coagulation is abnormal. Treat hepatic encephalopathy and consider antibiotic therapy (avoid tetracycline)
 2. Nutritional therapy
 a. An endoscopically placed gastrostomy tube is preferable long-term. Nasogastric (NG) tubes are adequate for short-term management. Force-feeding and appetite stimulating medications rarely achieve the needed caloric intake. Avoid diazepam, which has been associated with hepatic necrosis
 b. Provide 40 to 60 kcal/kg of body weight per day. Initially, give one fourth to one half of the amount divided into four to six feedings per day. Gradually increase the total amount fed over 3 to 4 days. Feed high-calorie high protein diet (unless there is hyperammonemia)
 c. Give metoclopramide or feed liquid enteral diet if vomiting occurs
 d. Dietary supplements such as B complex, cobalamin, thiamin, L-carnitine, taurine, vitamin E, and SAMe have been recommended, but efficacy studies are lacking
 E. Response to treatment and prognosis
 1. With aggressive therapy, 60% to 85% of the cats respond within 3 to 6 weeks. Early treatment is the key to successful treatment
 2. Remove feeding tube only when the cat is eating on its own for a least a week

3. Recurrence is rare and there is no evidence of residual hepatic damage
4. Closely monitor cats receiving a weight-reducing diet. Consider L-carnitine supplementation

VI. Canine vacuolar hepatopathies
 A. Glucocorticoid hepatopathy (steroid hepatopathy)
 1. A benign, reversible hepatic lesion caused by excess glucocorticoids either from exogenous administration (within 1 to 2 weeks of administration) or endogenous excess (hyperadrenocorticism, chronic stress). Glucocorticoids cause hepatic glycogen accumulation and hepatomegaly. Individual variation in susceptibility to steroid hepatopathy exists within dogs. Cats are resistant to hepatic effects of steroids
 2. There are no clinical signs of liver dysfunction. Clinical signs are related to the administered steroids or the underlying disease process
 3. Diagnosis
 a. Evaluate history for glucocorticoid therapy (including eye and ear medications, and topical creams)
 b. Increased serum ALP activity is most common (typically CiALP). Hematology may show a stress leukogram. Hepatomegaly is usually evident. Liver biopsy shows cytoplasmic vacuolization
 4. Steroid hepatopathy does not require any specific therapy for the liver. Treat the underlying condition, or decrease administered glucocorticoids. Time required for complete resolution is unpredictable (weeks to months)
 B. Vacuolar hepatopathy in Scottish terriers
 1. Similar to steroid hepatopathy and is associated with increased concentrations of adrenal steroids other than cortisol
 2. Most are asymptomatic; a few have mild polyuria or polydipsia, or other signs of hyperadrenocorticism
 3. Cortisol concentrations are normal with an ACTH stimulation test; adrenal sex hormones are usually increased
 4. No treatment is recommended if dogs are asymptomatic; otherwise, treat as for hyperadrenocorticism
 C. Vacuolar hepatopathy in hyperlipidemic miniature schnauzers
 1. Affected dogs typically develop a marked vacuolar (fat and glycogen) hepatopathy
 2. Clinical signs are usually due to the hyperlipidemia
 3. There may be a marked increase in ALP (mainly CiALP) and GGT activity
 4. Treat hyperlipidemia with a low-fat diet, fish oil, and vitamin E
 D. Superficial necrolytic dermatitis (hepatocutaneous syndrome)
 1. A crusting, ulcerative dermatopathy in dogs and cats which is associated with hepatopathy. Anticonvulsant drugs and exposure to mycotoxins may play a role. It is also associated with glucagon-producing pancreatic or hepatic tumors and pancreatic carcinoma
 2. Hyperglucagonemia stimulates hepatic utilization of amino acids during gluconeogenesis, causing severe hypoaminoacidemia resulting in a metabolic imbalance affecting the skin
 3. Common signs include skin lesions, lethargy, and inappetence. DM frequently develops in the later stages of the disease. A disease of older dogs, especially males
 4. Ultrasound shows a unique "honeycomb" appearance of the liver. Histopathology of the skin is pathognomonic (parakeratotic hyperkeratosis with epidermal hyperplasia). Nonregenerative anemia and mild to moderate increases in liver enzyme activity may be present
 5. Treatment involves surgical removal of glucagon-producing pancreatic tumor, administration of amino acid solutions, feeding of a high-protein diet, somatostatin analogue administration, and management of diabetes. Most dogs die or are euthanized within 5 months of the onset of skin lesions

VII. Canine chronic hepatitis is a heterogeneous group of necrotizing inflammatory diseases of the liver
 A. Hepatic copper accumulation and chronic hepatitis
 1. Hepatic copper concentration in normal dogs is less than 400 μg/g (ppm) dry weight. Copper accumulation causes significant hepatic injury (e.g., in Bedlington terriers) when concentration greater than 2000 μg/g
 2. Copper is normally excreted in the bile. Therefore, hepatic copper accumulation can be secondary to any cholestatic hepatic disorder
 B. Idiopathic chronic hepatitis
 1. Characterized by chronic portal inflammation, necrosis, and fibrosis, and frequently progresses to cirrhosis
 2. Common signs include anorexia, depression, polyuria or polydipsia, ascites, jaundice, weight loss, and vomiting. There is a higher incidence in females
 3. Serum ALT and ALP activity are markedly elevated. Hyperbilirubinemia and bilirubinuria are common. Liver function tests may be abnormal. Liver biopsy confirms the diagnosis
 4. Treat with glucocorticoids, ursodiol, antioxidants, and possibly azathioprine. Response to treatment varies
 C. Copper-associated hepatitis in Bedlington terriers
 1. Inherited (autosomal recessive) metabolic defect in biliary copper excretion that leads to progressive intrahepatic copper accumulation. Incidence within the breed is high (25% affected, 50% carriers). When hepatic copper accumulation is greater than 2000 μg/g dry weight, progressive hepatic injury occurs, including focal hepatic necrosis, chronic hepatitis, and eventually cirrhosis
 2. Clinical signs vary depending on the stage of disease. Middle-aged to older dogs usually present with signs of hepatic failure
 3. Laboratory evaluation findings vary with the stage of disease. Increased serum ALT activity is the most sensitive indicator, but it may be

normal in early stages. Acute release of copper from necrotic hepatocytes may cause hemolytic anemia. Liver biopsy is essential for the diagnosis
4. Treat with penicillamine to chelate copper. Oral zinc therapy may help prevent intestinal copper absorption. Vitamin E should be administered. If detected early, there is a good prognosis with life-long treatment
5. Bedlington terriers intended for breeding should have liver biopsy performed when older than 1 year. DNA testing (with 90% accuracy) is also available that can identify carriers, affected dogs, and unaffected dogs

D. Chronic hepatitis in West Highland white terriers
1. Hepatic copper accumulation is a familial trait, but the association with hepatitis is not clear
2. Dogs may be asymptomatic in early stages. Signs of hepatic failure occur with advanced disease
3. Increased ALT activity is the earliest indicator. Liver biopsy is required for definitive diagnosis. Copper granules, inflammation, necrosis, and cirrhosis may be evident
4. If hepatic copper is increased, treat as described for Bedlington terriers. Consider glucocorticoid therapy

E. Chronic hepatitis in Doberman pinschers
1. Hepatic copper concentration is increased in most; a genetic basis is suggested
2. Middle-aged females are predominantly affected. Signs may vary from mild in early stages to signs of severe hepatic failure with advanced disease
3. Laboratory findings include increased liver enzyme activity, hyperbilirubinemia, abnormal liver function, and coagulopathy. A small liver and ascites are evident. Liver biopsy is required for a definitive diagnosis. Copper accumulation is mild to moderate
4. Treat with immunosuppressive drugs, possibly penicillamine. Response to treatment is poor

F. Copper-associated hepatitis in dalmatians
1. Chronic hepatitis with hepatic copper accumulation and without significant cholestasis is suggestive of familial metabolic disorder rather than secondary copper accumulation
2. Most present with acute GI signs
3. ALT is markedly increased, and ALP is moderately increased. Liver biopsy shows increased copper concentration
4. Copper chelation therapy is beneficial in early stages. Rapid progression is characteristic

G. Copper-associated hepatitis in Skye terriers
1. Chronic hepatitis and cirrhosis
2. Speculated to be a result of disturbed bile secretion with secondary accumulation of copper

H. Chronic hepatitis in cocker spaniels
1. The cause is unknown. Copper accumulation is not a consistent feature
2. Ascites is the most common clinical sign. Males are at increased risk
3. Liver enzymes activity may be normal to moderately increased. Serum bilirubin concentration is normal to mildly increased. Liver function tests are abnormal
4. Corticosteroid therapy may be beneficial. Prognosis is poor

I. Lobular dissecting hepatitis
1. A distinctive histologic form of chronic hepatitis that occurs in young dogs. It has been suggested that this is a specific reaction pattern of the liver in juvenile dogs to a variety of hepatic insults. Standard poodles may be at increased risk
2. Clinical signs consistent with advanced hepatic failure and portal hypertension
3. Liver biopsy required for diagnosis. Increased liver enzymes and abnormal liver function tests are present

J. Acidophil cell hepatitis
1. Probably viral; characterized by acute or chronic hepatitis slowly progressing to cirrhosis
2. No known specific treatment

VIII. Feline inflammatory liver disease is the second most common liver disease in cats

A. Neutrophilic cholangitis is most common and is caused by ascending bacterial infection from the intestine into the biliary tract. Other possible causes include viral, liver flukes, *Toxoplasma*-like organisms, *Hepatozoon canis*, toxin-induced, or drug-induced disease
1. Clinical signs include vomiting, anorexia, lethargy, and weight loss. Signs of hepatic encephalopathy and ascites, and excessive bleeding may occur with biliary cirrhosis. Commonly associated with IBD and chronic subclinical pancreatitis (“triaditis”)
2. Diagnosis
 a. Onset may be acute or chronic. Young cats typically have an acute onset; usually chronic in middle-aged to older cats
 b. Liver enzyme activity is variable. Increased ALT and bilirubin levels are common
 c. The liver may appear normal to enlarged. Liver biopsy is required for definitive diagnosis
3. Supportive case and antibiotic therapy are recommended. Prednisolone may be required in chronic cases. Ursodiol is recommended for all cats, with the addition of SAMe or vitamin E. Avoid dietary protein restriction unless necessary
4. The acute form may resolve with treatment, or may progress to a chronic form. The chronic form requires long-term treatment

B. Lymphocytic cholangitis
1. Infiltration of small lymphocytes in portal areas, with variable bile duct proliferation, and possibly progressive fibrosis. Persian cats may be predisposed
2. Findings include ascites, jaundice, lymphadenopathy, and hyperglobulinemia in young cats
3. Treatment is similar to chronic neutrophilic cholangitis

C. Lymphocytic portal hepatitis
1. Lymphocytic infiltration of portal areas
2. Common in older cats, often with no clinical signs or laboratory abnormalities

IX. Phenobarbital-associated hepatic disease
A. The mechanism of hepatic injury is unknown. Higher doses, higher blood levels (greater than 40 μg/mL), and long duration appear to be important
B. Clinical signs are consistent with chronic hepatic failure. Seizures may increase with the development of hepatic encephalopathy
C. Increases in ALT and ALP activity greater than 5 times the upper limit of normal and increased AST activity may indicate hepatic injury rather than microsomal enzyme induction by phenobarbital. Hyperbilirubinemia and increased serum bile acids (SBA) concentration may indicate significant hepatic damage
D. If possible, gradually discontinue phenobarbital and replace with potassium bromide
E. To prevent, monitor serum concentration and adjust the dosage of phenobarbital so that concentrations do not exceed 35 μg/mL. Routinely monitor dogs on chronic phenobarbital therapy

X. Hepatic amyloidosis
A. Reactive amyloidosis (secondary to chronic inflammatory, infectious, or neoplastic disorders) affects the liver, kidneys, spleen, and adrenal glands. It is familial in Chinese shar-pei dogs and in Abyssinian cats. Diffuse hepatic involvement predisposes to spontaneous hepatic rupture
B. Clinical signs of renal failure are most common. Jaundice or liver rupture may occur
C. Hepatomegaly is present, with increased ALT, bilirubin, and bile acid concentrations. Hepatic cytology may suggest the presence of amyloid, which appears as pink amorphous material. Congo-red staining is required for confirmation
D. Treat with fluid therapy, blood transfusion, and vitamin K. Colchicine therapy may be beneficial. Long term prognosis is poor

XI. Hepatic cirrhosis and fibrosis
A. Irreversible end stage of chronic hepatic injury. Clinical signs are characteristic of generalized hepatic dysfunction
B. Diagnosis
1. Increases in serum liver enzymes are usually more modest than during acute disease. Serum concentrations of bilirubin, ammonia, and bile acids usually are increased; albumin usually is decreased. Hemostatic abnormalities may occur as a result of impaired coagulation factors synthesis or DIC
2. Ultrasonography may reveal small liver in dogs but hepatomegaly in cats
3. Liver biopsy is required for definitive diagnosis
C. Treatment is mainly supportive to control complications

XII. Hepatobiliary neoplasia
A. Hepatocellular carcinoma is the most common primary hepatic tumor in dogs. Biliary carcinomas and adenomas are the most common primary hepatic tumors in cats
B. Clinical signs are usually vague and appear at advanced stages; weight loss and anorexia are common. Ascites is more common in dogs compared with cats. Neoplasia typically occurs in older dogs and cats. Labrador retrievers may have an increased risk for biliary carcinoma
C. Diagnosis
1. Laboratory findings are consistent with hepatic disease. Hypoglycemia may be noted, and there may be coagulation deficits
2. Abdominal radiographs show hepatomegaly and ascites. Thoracic radiographs may reveal metastases. Liver biopsy is required for a definitive diagnosis
D. Surgical excision of solitary masses is the treatment of choice. Chemotherapy is not effective. When multiple lobes are affected, the prognosis is poor

XIII. Hepatic nodular hyperplasia
A. Cause unknown; common in older dogs. The number, size, and distribution of the nodules are variable
B. Not associated with clinical signs
C. May cause mild to moderate increases in activity of liver enzymes. Liver function tests are normal
D. A wedge biopsy is required for differentiation from hepatocellular neoplasia
E. No treatment is required

XIV. Hepatic cysts
A. May be congenital, or acquired (trauma, neoplasia, *Bartonella henselae*)
B. Clinical signs are absent unless the cysts compress adjacent tissue
C. Diagnosis is by imaging; remove with surgery

XV. Congenital PSSs
A. Congenital PSSs are vascular communications between the portal and systemic venous systems. These communications allow enterically derived toxins to reach the systemic circulation
1. Intrahepatic congenital PSS result from failure of the fetal ductus venosus to close. The shunt connects the portal vein and caudal vena cava, often via the left hepatic vein. This type is most common in large-breed dogs
2. Extrahepatic congenital PSS result from developmental malformation of the vitelline system. The shunt connects the portal vein (or left gastric or splenic vein) with the caudal vena cava cranial to the phrenicoabdominal veins or azygous vein. This type is most common in small-breed dogs and cats
B. Clinical signs
1. CNS: Signs of hepatic encephalopathy are most common and tend to wax and wane. Signs include weakness, ataxia, head pressing, circling, behavioral changes, blindness, seizures, and coma. Hypersalivation, seizures, and blindness are common in cats
2. GI: Intermittent anorexia, vomiting, and diarrhea are common. Stunted growth may occur
3. Urinary: Urate urolithiasis results from increased urinary excretion of ammonia and uric acid. Psychogenic polydipsia with subsequent polyuria is common

C. Diagnosis
 1. More common in purebred dog, but more common in domestic shorthaired cats. No sex predilection. Most develop clinical signs by 6 months of age
 2. History and physical examination may reveal stunted growth, prolonged recovery from anesthesia, or exacerbation of signs after a protein-rich meal. Many cats have copper-colored irises
 3. Laboratory evaluation consistent with hepatic dysfunction without significant necrosis and cholestasis. Hematologic findings include microcytosis, target cells, and poikilocytosis. Mild nonregenerative anemia may occur. Serum ALT and ALP levels are normal to mildly increased. Postprandial concentrations of serum bile acids are consistently increased. Coagulation tests are normal
 4. Radiography reveals a small liver in dogs; mild renomegaly is common. Intrahepatic shunts may be detected with ultrasound. Positive-contrast portography is the procedure of choice to characterize PSS (Figure 16-4)
 5. Liver biopsy shows hepatocyte atrophy with small or absent portal veins

D. Treatment
 1. Surgery: The treatment of choice is surgical attenuation or complete ligation of the shunt. Gradual progressive closure (using ameroid constrictors or cellophane bands) is preferable
 2. Medical therapy is palliative; may control signs up to 2 to 3 years
 a. Therapy for hepatic encephalopathy (protein-restricted diet, lactulose, neomycin)
 b. Management of urate urolithiasis
 c. Manage seizures with anticonvulsant therapy

E. Prognosis is excellent in dogs with total surgical ligation. With medical management, prognosis is good short-term, but poor long-term

XVI. Multiple extrahepatic PSSs
 A. Develop as a compensatory response to sustained portal hypertension
 B. Treat the underlying disorder. Do not ligate the shunting vessels

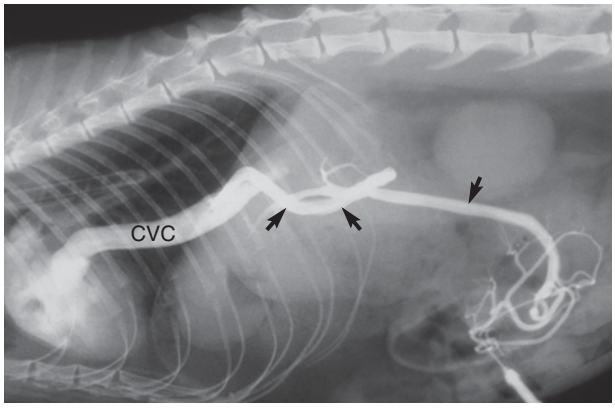


Figure 16-4 Lateral intraoperative mesenteric portogram of a cat. A large extrahepatic shunt vessel *(arrowheads)* originates from a branch of the portal vein (arrow) and terminates at the caudal vena cava *(CVC)*. (Courtesy of Dr. Daniel Brockman.)

XVII. Hepatic microvascular dysplasia (HMD)
 A. Congenital microscopic hepatic vascular abnormalities that result in increased serum bile acids concentrations. Inherited in Cairn terriers
 B. Clinical signs are similar to those with congenital PSS
 C. Mainly small-breed dogs (Yorkshire terriers, Cairn terriers). Older at presentation than those with congenital PSS
 D. Signs of hepatic encephalopathy with failure to identify shunting
 E. Provide dietary management as for PSS once clinical signs appear

XVIII. Primary portal vein hypoplasia (PPVH)
 A. A congenital abnormality of portal vascular development, predominantly small intrahepatic portal venules, but hypoplasia of the extrahepatic portal vein may occur in 30% of dogs. Young, medium- to large-breed dogs are at risk
 B. Clinical signs include abdominal distension from ascites and signs of hepatic encephalopathy
 C. Clinical findings and imaging are consistent with a small liver and PSS
 D. There is no specific therapy. Control consequences of portal hypertension and PSS

XIX. Hepatic arteriovenous fistula (AVF)
 A. Vascular communications between the hepatic artery and the portal vein that result in portal hypertension, ascites, and secondary PSS. May be congenital or acquired
 B. Clinical signs are due to ascites and PSS
 C. A continuous murmur may be auscultated on the abdominal wall over the area of the liver
 D. Radiographs indicate ascites, and laboratory findings are consistent with hepatic dysfunction
 E. Partial hepatectomy is indicated when one lobe is involved. Medical management is indicated if PSS is present

XX. Cholecystitis
 A. Predisposing factors include cholelithiasis, anatomic malformation of the gallbladder, biliary obstruction, and biliary surgery
 B. Clinical signs may be acute or chronic, persistent or episodic, and include fever, abdominal pain, hepatomegaly, jaundice, vomiting, and diarrhea
 C. Diagnosis is based on radiography or ultrasonography, and biochemical findings consistent with severe cholestasis
 D. Treat by cholecystectomy

XXI. Gallbladder mucocele
 A. Abnormal accumulation of mucus in the gallbladder lumen accompanied by cystic mucosal hyperplasia of the gallbladder mucosa. Hyperadrenocorticism or corticosteroid therapy appears to be a risk factor
 B. Clinical signs occur with secondary bacterial infection, obstruction or rupture, or ischemic necrosis

C. Occurs mostly in older small- to medium-sized dogs. Cocker spaniels and Shetland sheepdogs may be predisposed
D. Diagnosis is based on ultrasound findings. Liver enzymes (ALP, ALT, AST, GGT) may also be elevated
E. Cholecystectomy is the treatment of choice

XXII. Cholelithiasis
A. Predisposing factors include bile stasis, inflammation of bile ducts and gallbladder, β-glucuronidase containing bacteria, and taurine-deficient diet
B. Clinical signs include jaundice, and GI signs, but are often absent
C. Older, small-breed female dogs may be at increased risk
D. Laboratory findings may indicate cholestatic disease. Choleliths can be detected with ultrasonography
E. Remove surgically if infection, obstruction, or perforation is present

XXIII. Extrahepatic biliary obstruction
A. Caused by a complication of a primary biliary disorder, or an extrahepatic disorder
B. Clinical signs include jaundice, abdominal pain, vomiting, and diarrhea
C. Laparotomy is usually required to confirm. Biochemical findings indicate marked cholestasis, and coagulation tests may be abnormal
D. Surgical treatment is necessary

XXIV. Biliary rupture
A. Usually caused by abdominal trauma, but can be primary. Leakage of bile results in peritonitis
B. Clinical signs include acute jaundice, abdominal pain, fever, vomiting, and diarrhea
C. Diagnosis
1. Biochemical findings include hyperbilirubinemia, increased ALP, ALT activity, and serum bile acids concentration
2. Abdominal fluid analysis reveals bilirubin concentration higher than the serum concentration. Cytologic evaluation reveals mixed inflammatory infiltrate, bile-laden macrophages, or free green-brown material. Bacteria may be detected
3. Abdominal radiographs may indicate abdominal effusion. On ultrasonography, abdominal fluid is evident and gallbladder may not be visible
D. Surgical correction is required. Treat with appropriate antibiotics and vitamin K

XXV. Surgery of the liver (see Chapter 27 for a review of surgical procedures)
A. Preoperative considerations include the presence of hypoproteinemia, anemia, coagulopathy, impaired liver function, and hypoglycemia
B. Tru-Cut needle or skin biopsy punch may be used to obtain small pieces of liver tissue, especially if the lesion is centrally located in the liver lobe
C. Postoperatively, monitor for hemorrhage, pancreatitis, and liver function

EXOCRINE PANCREAS DISORDERS

I. Pancreatitis
A. Cause is not identified in most cases. Predisposing factors may include hyperlipidemia, reflux of duodenal contents into the pancreatic duct, obstruction of the pancreatic duct, biliary or GI disease, infection (*Toxoplasma gondii*, pancreatic or liver flukes), hypercalcemia, hyperstimulation, idiosyncratic drug reactions, zinc toxicosis, pancreatic trauma, or genetic predisposition. Impaired pancreatic microcirculation is a key factor in progression to severe necrotizing pancreatitis
B. Clinical signs
1. In dogs, a history of a recent high-fat meal is common. The most common signs are vomiting and abdominal pain. Pancreatitis is most frequent in middle-aged to older dogs
2. In cats, clinical signs include lethargy, anorexia, and weight loss, with or without vomiting
3. Complications include shock, peritonitis, biliary obstruction, hepatic lipidosis (cats), hyperglycemia, DIC, acute renal failure, cardiac arrhythmias, and respiratory distress. Chronic complications include pancreatic abscess, chronic relapsing pancreatitis, pancreatic fibrosis and atrophy (resulting in DM or EPI), and liver disease
C. Diagnosis
1. Neutrophilic leukocytosis is common in dogs. Thrombocytopenia and RBC fragments may indicate DIC
2. Serum amylase and lipase may be increased in dogs but lack specificity and sensitivity for the diagnosis of pancreatitis. Liver enzymes may be elevated, and fasting hyperlipidemia is common. Metabolic acidosis, hypokalemia, and hypocalcemia may occur
3. Serum trypsin-like immunoreactivity (TLI) assay may be increased in pancreatitis
4. Serum pancreatic lipase immunoreactivity (PLI) assay detects pancreas-specific lipase. Both sensitivity and specificity are high for pancreatitis
5. C-reactive protein is a marker of systemic inflammation that is increased in pancreatitis
6. Ultrasonography is more sensitive for the detection of pancreatitis than radiography. Changes include irregular pancreatic enlargement, decreased echogenicity of the pancrease, and peripancreatic effusion
7. Pancreatic biopsy may be required for a diagnosis
D. Medical treatment provides supportive care and allows the pancreas to rest
1. Fluid and electrolyte therapy is used to correct dehydration
2. Vomiting is controlled with antiemetics
3. Avoid NSAIDs for controlling pain due to the risk of GI ulceration
4. Oral pancreatic enzymes may be beneficial
5. Treat complications as needed
6. Food intake should be reinstituted as soon as possible. Feed a diet restricted in fat and protein

E. Surgical treatment is rarely indicated, and is used only in those that fail to respond to medical therapy, or have pancreatic abscess, biliary obstruction, or septic peritonitis

II. Exocrine pancreatic insufficiency (EPI)
 A. Causes
 1. Occurs when 90% or more of pancreatic secretory capacity is lost
 2. The most common cause in dogs is pancreatic acinar atrophy (PAA). High incidence in German shepherd dogs and collies. PAA is inherited
 3. Chronic pancreatitis may result in EPI
 B. Clinical signs include maldigestion with chronic diarrhea, pale, fatty feces, weight loss, increased appetite. Usually occurs in young dogs if due to PAA. A history of chronic pancreatitis may be present
 C. Diagnosis
 1. Routine hematology, serum chemistries, urinalysis, and radiographs are generally unremarkable
 2. TLI is highly sensitive and specific for EPI and is not affected by intestinal disease. Serum PLI is less accurate for the diagnosis of EPI
 3. Fecal proteolytic activity is decreased in EPI but is less accurate that TLI
 4. Fecal elastase activity may be useful
 5. Serum cobalamin is frequently decreased in EPI but is also decreased in chronic intestinal disease
 D. Treatment
 1. Pancreatic enzyme replacement therapy is required for life
 2. Feed a highly digestible, low-fiber, low-fat diet. Supplement with vitamin E and cobalamin if required. Cats may require folate and vitamin K
 3. In those that fail to respond, treat with antibiotics, administer an oral H_2 receptor blocker with meals, and reassess the diagnosis

III. Exocrine pancreatic neoplasia
 A. Usually adenocarcinomas which are aggressive with early metastasis
 B. Clinical signs are similar to chronic pancreatitis. Metastases may result in jaundice, severe vomiting, abdominal effusion, paraneoplastic alopecia, hyperkeratosis, or footpad lesions
 C. Diagnosis: Chemistry profile findings resemble those in chronic pancreatitis. Biopsy is required in most cases for a diagnosis
 D. Pancreatectomy may be palliative but is not curative. The prognosis is grave

PERITONITIS

I. Causes
 A. Primary peritonitis occurs in cats (FIP)
 B. Secondary peritonitis occurs in most cases. Causes include GI perforation or leakage, urinary tract leakage, biliary tract leakage, pancreatitis, extension of infection from other organs, leakage of chyle, or iatrogenic

II. Distribution
 A. Local peritonitis: Inflammation is confined; does not require surgical management
 B. Diffuse peritonitis: Requires aggressive medical and surgical therapy

III. Clinical signs include abdominal pain, fever, vomiting, dehydration, and shock

IV. Diagnosis
 A. History and physical examination. Findings of hematemesis, melena, or hematochezia increase suspicion of bowel perforation
 B. Diagnostic tests
 1. Fluid analysis indicates large numbers of neutrophils (greater than 500/μL). Additional findings include bacteria on cytology and decreased glucose concentration compared to serum. Increased bilirubin, creatinine, or amylase concentrations compared with serum may be present, depending on underlying cause
 2. Hematology: Neutrophil toxicity with left shift indicates significant inflammation. A degenerative left shift suggests overwhelming inflammation. Anemia may be present
 3. Serum chemistry profile may indicate hypoproteinemia, hypoglycemia, azotemia, hyperkalemia, hyperbilirubinemia, or increased amylase and lipase, depending on the underlying cause
 C. Radiography may show loss of contrast and detail. Ultrasound can confirm the presence of abdominal fluid

V. Treatment
 A. Medical management involves correction of dehydration and electrolyte abnormalities, and systemic antibiotics
 B. Surgical management with lavage and drainage may be required if the peritonitis is moderate or severe, is not improving with medical treatment, or is due to a surgical lesion

Supplemental Reading

Birchard SJ. Peritonitis. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 853-860.

Johnson SE, Sherding RG. Diseases of the esophagus and disorders of swallowing. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 636-654.

Johnson SE, Sherding RG. Diseases of the liver and biliary tract. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. Saunders, St Louis, 2006, pp. 747-809.

Johnson SE, Sherding RG, Bright RM. Diseases of the stomach. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 664-690.

Marretta, SM. Dentistry and diseases of the oropharynx. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 609-635.

Section XIV, Gastrointestinal Disease. In Ettinger SJ, Feldman EC, eds. *Textbook of veterinary internal Medicine,* 6th ed. St Louis, 2005, Saunders, pp. 1290-1420.

Section XV, Liver and Pancreatic Diseases. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders, pp. 1422-1495.

Sherding RG. Constipation and anorectal diseases. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 831-844.

Sherding RG, Johnson SE. Diseases of the intestines. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 702-738.

Sherding RG, Birchard SJ, Johnson SE. Diseases and surgery of the exocrine pancreas. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 819-830.

17 CHAPTER

Hematology

Patricia A. Schenck

ERYTHROCYTE DISORDERS

I. Anemias
 A. Blood loss anemia
 1. Causes include trauma, surgery, parasites (external and internal), gastric ulcers, gastrointestinal (GI) tumors, urinary tract tumors, splenic rupture, coagulation disorders
 2. Treatment is administration of whole blood if packed cell volume (PCV) drops acutely below 20% in the dog or 25% in the cat
 B. Hemolytic anemia
 1. Congenital
 a. Pyruvate kinase (PK) deficiency
 (1) Autosomal recessive in basenji, beagle, West Highland white terrier, Cairn terrier, American Eskimo dog, miniature poodle, Chihuahua, pug; Abyssinian, Somali, and domestic short hair (DSH) cats
 (2) Young animals
 (3) Anemia, exercise intolerance, tachycardia, splenomegaly; death by 4 years of age usually
 (4) Intense reticulocytosis, frequent nucleated red blood cells (RBCs)
 (5) Polymerase chain reaction (PCR) genetic test available for some breeds
 b. Phosphofructokinase deficiency
 (1) Autosomal recessive in English springer spaniels and American cocker spaniels
 (2) Increased intracellular pH increases fragility of RBCs
 (3) Hypoxia, intravascular hemolysis, hemoglobinuria, bilirubinuria, persistent reticulocytosis
 (4) Lethargy, hepatosplenomegaly, myopathy, fever. May live a normal lifespan
 (5) PCR genetic test available
 c. Hereditary stomatocytosis
 (1) Autosomal recessive in Alaskan malamutes in association with chondrodysplasia
 (2) Mild anemia with slight reticulocytosis
 d. Feline porphyria
 (1) Enzyme deficiency affects synthesis of heme
 (2) Pink urine, pink-brown teeth, severe anemia, skin photosensitization
 (3) RBCs lyse when exposed to sunlight
 e. Hereditary nonspherocytic hemolytic anemia
 (1) Autosomal dominant in poodles
 (a) Resembles PK deficiency
 (b) Persistent macrocytic hypochromic anemia; moderate reticulocytosis
 (c) Fatal by 3 years of age
 (2) Autosomal recessive in beagles
 (a) Can remain undetected for years
 (b) Short RBC lifespan
 2. Immune-mediated hemolytic anemia (see below)
 3. Infectious causes of hemolysis
 a. Hemoplasmosis (hemobartonellosis)
 (1) Caused by *Mycoplasma haemocanis* in dogs and *Mycoplasma haemofelis* in cats
 (2) Transmitted by ticks and fleas or from queens to newborn kittens
 (3) Immunosuppression or splenectomy predisposes
 (4) Clinical signs are associated with anemia
 (5) Epicellular organisms are found on blood smears; dogs usually have linear chains of organisms, whereas cats usually have coccoid or ring shapes. PCR tests are available for cats (Figure 17-1)
 (6) Treat with doxycycline. Prednisolone may be needed to suppress the destruction of RBCs. Enrofloxacin can be used in cats if they do not tolerate doxycycline. May need blood transfusions. Cats may become latent carriers
 b. Babesiosis
 (1) Caused by *Babesia canis* or *Babesia gibsoni* in dogs. *Babesia felis* affects cats (but has not been found in North America). *B. canis* has been associated with greyhounds, and *B. gibsoni* has been associated with pitbulls and American Staffordshire terriers
 (2) Transmitted by ticks
 (3) Clinical signs are associated with anemia and range from an acute hemolytic crisis to subclinical signs
 (4) Large teardrop-shaped organisms are seen in RBCs on blood smear. Smaller signet ring-shaped forms suggest *B. gibsoni*. Immunofluorescent antibody (IFA) and PCR tests are available (Figure 17-2)
 (5) Treat with imidocarb dipropionate

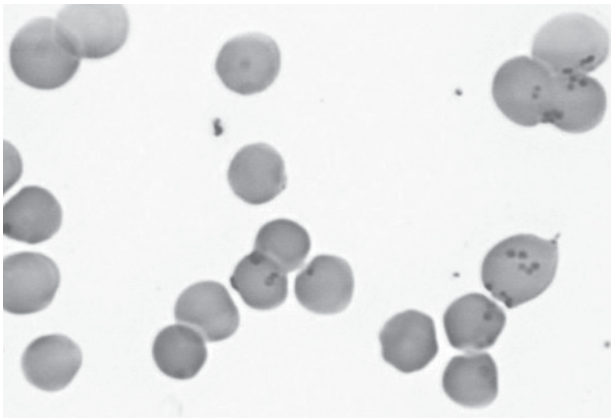


Figure 17-1 This blood smear from a domestic cat shows a high proportion of the red blood cells with single scattered or short chains of basophilic cocci or faint rings on the cell membrane that are characteristic of *Mycoplasma haemofelis* organisms. (Diff-Quik stain, original magnification 400×.) (From Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St. Louis, 2008, Mosby.)

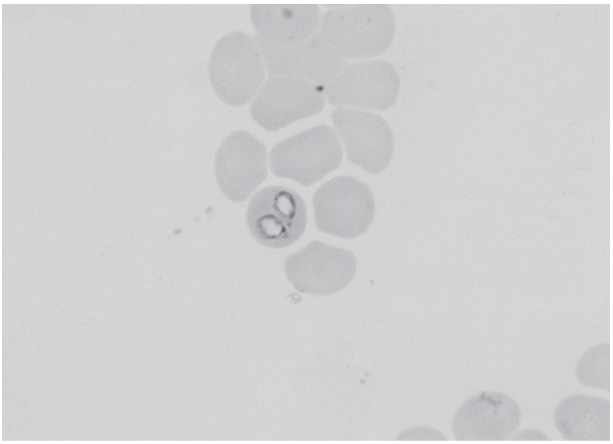


Figure 17-2 Peripheral blood from a dog with a *Babesia canis* infection. Two piroplasms are seen in a single red blood cell in this field. (Wright's stain, original magnification 330×.) (From Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St. Louis, 2008, Mosby.)

c. Leptospirosis can cause hemolysis and coagulopathies. (See section on infectious diseases)

4. Chemical or toxic injury of erythrocytes
 a. Heinz body anemia
 (1) Produced by oxidant agents that precipitate hemoglobin; this leads to accelerated RBC destruction
 (2) Agents responsible include acetaminophen, methylene blue, onions, zinc, vitamin K_3, methionine, and propylene glycol
 (3) In cats, Heinz bodies may be associated with hyperthyroidism, lymphoma, and ketoacidosis
 (4) Clinical signs include hemoglobinemia, hemoglobinuria, moderate to severe anemia, and icterus
 (5) Heinz bodies appear as a large pale-staining area in RBCs or may appear as a blunt projection bulging from the RBC membrane surface. Eccentrocytosis has been associated with onion and garlic ingestion in dogs (Figure 17-3)
 (6) Treatment is to remove the source of oxidant; give blood transfusions and supportive care. Acetominophen toxicity is treated with acetylcysteine
 b. Snake venom (coral snakes, rattlesnakes) can cause hemolysis. Echinocytosis may be observed
 c. Zinc toxicity can cause intravascular hemolysis in dogs. Sources of zinc include galvanized wire (from kennel cages), fishing sinkers, and pennies (since 1983). Regenerative anemia results, sometimes with Heinz bodies and spherocytosis
5. Mechanical ragmentation of erythrocytes
 a. Heartworms obstruct blood flow, resulting in anemia from intravascular hemolysis. Schistocytosis, hemoglobinemia, and hemoglobinuria are noted. (See section on cardiovascular disorders)
 b. Disseminated intravascular coagulopathy (DIC) causes a microangiopathic hemolytic anemia from fibrin deposition in damaged small blood vessels. Thrombocytopenia, decreased clotting factors, and increased fibrin degradation products are noted
 c. Hypophosphatemia associated with feline diabetes mellitus and hepatic lipidosis may cause hemolysis

C. Nonregenerative anemia
1. Infectious agents
 a. Feline leukemia virus (FeLV) causes a normochromic, normocytic to macrocytic anemia. Severe RBC hypoplasia is common
 b. Other viruses, such as feline infectious peritonitis (FIP), feline immunodeficiency virus (FIV), feline panleukopenia virus, canine parvovirus, and canine distemper virus, can cause mild to moderate anemia because of the suppression of erythropoiesis

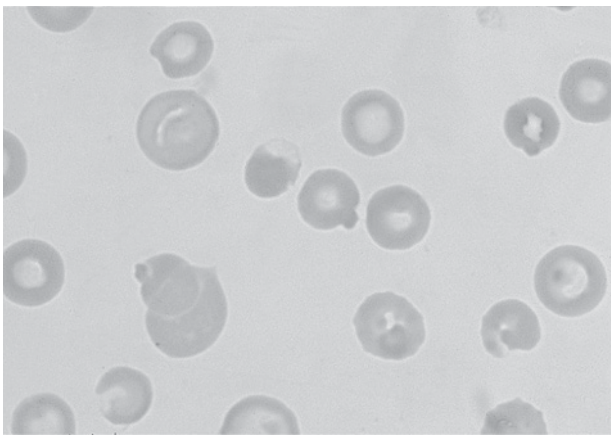


Figure 17-3 Three canine erythrocytes with large Heinz bodies and an eccentrocyte (center) can be seen in this field. (Wright's stain, original magnification 330×.) (From Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St. Louis, 2008, Mosby.)

c. Rickettsial diseases such as *Ehrlichia* and *Anaplasma* are associated with mild to moderate nonregenerative anemia, along with thrombocytopenia, leukopenia, or pancytopenia. Intracytoplasmic morulae are sometimes observed in mononuclear cells or granulocytes
d. Leishmaniasis may cause a mild to moderate normocytic, normochromic anemia
e. Cytauxzoonosis causes moderate anemia, leukopenia, and thrombocytopenia, and is highly fatal

2. Nutritional deficiencies
 a. Iron deficiency causes a poorly regenerative anemia from deficient hemoglobin synthesis
 (1) Caused by neoplasia, trauma, parasites, coagulopathies, and GI diseases causing blood loss
 (2) RBCs show hypochromasia and poikilocytosis
 (3) Thrombocytosis is common
 b. Cobalamin (vitamin B_{12}) deficiency causes normocytic, normochromic, nonregenerative anemia
 c. Folate deficiency produces a macrocytic anemia
3. Inflammatory diseases frequently cause nonregenerative anemia
 a. Cytokine release leads to decreased erythropoiesis, reduced iron availability, and decreased RBC survival
 b. Bone marrow is hypocellular
4. Organic diseases
 a. Chronic renal disease may be accompanied by normocytic, normochromic, nonregenerative anemia
 b. Liver disease is associated with normocytic, nonregenerative anemia. Poikilocytosis is common
5. Endocrine diseases
 a. Hypothyroidism may cause mild anemia
 b. Hyperestrogenism causes moderate to severe anemia with thrombocytopenia and leukopenia
 c. Hypoadrenocorticism may cause a nonregenerative anemia
6. Drug and toxin-induced diseases
 a. Drugs inducing anemia include estrogens, phenylbutazone, antineoplastic agents, trimethoprim-sulfadiazine, thiacetarsamide, quinidine, meclofenamic acid; decreased erythropoiesis and aplastic anemia
 b. Lead toxicity
 (1) Mild anemia; basophilic stippling observed
 (2) Large numbers of nucleated RBCs with normal or decreased PCV
7. Myelophthisis occurs when abnormal cellular infiltrates crowd the bone marrow, suppressing hematopoiesis
 a. Neoplasia from primary hemolymphatic tumors or metastatic tumors
 b. Myelofibrosis occurs when bone marrow is damaged by inflammation, necrosis, neoplasia, toxic agents. It is also associated with myelodysplastic syndrome and acute myelogenous leukemia in cats. Bone marrow aspirate produces only blood, with few to no marrow particles
 c. Myelonecrosis results from direct injury to endothelium or occlusion of microcirculation
 d. Osteopetrosis is an inherited condition resulting in obliteration of marrow cavities by bone, with resulting anemia or pancytopenia in young dogs
8. Irradiation can result in pancytopenia and aplastic bone marrow
9. Pure erythrocyte aplasia is a significant reduction in erythroid stem cells, with no effect on granulocytic or megakaryocytic lines

II. Polycythemia
 A. Relative polycythemia
 1. Usually due to dehydration or hemoconcentration. Splenic contraction from excitement can also cause a transient increase in PCV. Greyhounds normally have a higher PCV (about 60%)
 2. Mucous membranes are dark red and have a slow capillary refill time
 B. Absolute polycythemia
 1. Primary erythrocytosis (polycythemia vera) results from a stem cell defect, with low serum erythropoietin concentrations
 2. Secondary erythrocytosis is a result of overproduction of erythropoietin resulting from hypoxia, erythropoietin-producing tumors, or pyelonephritis

III. Methemoglobinemia
 A. Occurs from oxidation of iron in hemoglobin. Oxidized hemoglobin cannot bind oxygen, resulting in hypoxia. Blood appears dark red or chocolate-colored
 B. Results from exposure to oxidant drugs and chemicals. Methemoglobinemia often occurs at the same time as Heinz bodies appear, but methemoglobinemia usually occurs first
 C. Treatment is similar to Heinz body anemia

LEUKOCYTE DISORDERS

I. Congenital disorders
 A. Pelger-Huet anomaly
 1. Inherited disorder of granulocyte maturation
 2. Nuclei of neutrophils often look like band cells, metamyelocytes, or myelocytes
 3. No clinical signs; treatment not necessary
 B. Feline Chediak-Higashi syndrome
 1. Rare; occurs in blue-smoke Persian cats with yellow eyes
 2. Neutrophils contain large pink cytoplasmic inclusions
 3. Abnormal lysosomal granule formation in granulocytes and monocytes
 C. Lysosomal storage disease
 1. Mucopolysaccharidosis and gangliosidosis
 a. Inherited; caused by enzyme deficiency
 b. Neutrophils contain coarse, red-purple granules when stained. Must distinguish these from toxic neutrophils

c. Urine test for glycosaminoglycans. Also cell enzyme activity tests
2. Other disorders cause lymphocyte vacuolation abnormalities. Affected lymphocytes have multiple cytoplasmic vacuoles

D. Abnormal granulation syndrome in Birman cats
1. Pink-purple granules within neutrophil cytoplasm
2. No clinical signs

II. Neutrophil disorders
A. Neutrophilia
1. Physiologic resulting from the release of epinephrine (transient increase). More common in cats
2. Corticosteroid administration
3. Inflammation
a. Infectious
b. Noninfectious such as in pancreatitis, tissue necrosis, thrombosis, and burns
c. Neoplasia such as metastatic fibrosarcoma or renal tubular carcinoma
d. Severe abscessation such as pyometra
e. Immune-mediated such as systemic lupus erythematosus
f. Granulocytopathy syndrome in Irish setters. Neutrophils have impaired bactericidal activity as a result of adhesion defects
4. Paraneoplastic syndrome

B. Neutropenia
1. Congenital cyclic neutropenia
a. Inherited disorder of gray collies
b. Cyclic decrease of neutrophils, platelets, and monocytes in 12-day intervals
2. Infection causes a degenerative left shift with an increase of immature cells
a. Gram-negative bacteria
b. *Toxoplasma*
c. Systemic fungal disease
d. Viruses such as FeLV, FIV, feline panleukopenia virus, canine parvovirus
e. *E. canis*
3. Drugs: Many antibiotics (e.g., chloramphenicol, trimethoprim-sulfadiazine), antineoplastic agents, and nonsteroidal antiinflammatory drugs (NSAIDs) can cause neutropenia
4. Endotoxins from gram-negative bacteria
5. Immune-mediated neutropenia is due to destruction of antibody-coated neutrophils by macrophages. Drugs responsible include methimazole and cephalosporins

III. Monocytosis
A. From corticosteroid administration (along with neutrophilia, lymphopenia, and eosinopenia)
B. Inflammatory processes that cause a demand for macrophages
C. Neoplasia (see leukemic disorders below)

IV. Eosinophils
A. Eosinophilia
1. Parasites in skin, respiratory tract, or GI tract
2. Parasites include *Ancylostoma*, *Trichuris vulpis*, *Toxocara canis*, *Dirofilaria immitis*, *Dipetalonema reconditum*, lungworms, and *Paragonimus kellicotti*
3. Allergies result in the production of immunoglobulin E (IgE) with mast cell degranulation and attraction of eosinophils
4. Tumors such as fibrosarcoma, mammary carcinoma, mast cell tumors, and T-cell lymphomas (cats)
5. Feline hypereosinophilic syndrome
a. Infiltration of eosinophils into organs
b. Cause unknown
c. Resembles leukemia of well-differentiated eosinophils
d. Clinical signs include anorexia, weight loss, fever, vomiting, diarrhea, and lymphadenopathy
e. Death results from organ infiltration

B. Eosinopenia from exogenous or endogenous corticosteroids

V. Basophilia
A. Parasites such as heartworms or hookworms
B. Allergies cause IgE production with increased mast cells and basophils
C. Hyperlipemia can result in basophilia
D. Systemic mastocytosis

VI. Lymphocyte disorders
A. Lymphocytosis
1. Transient lymphocytosis can occur with stress or extreme exertion
2. Infectious lymphocytosis can occur from antigen stimulation in FeLV, *E. canis*, *Rickettsia rickettsii*, and fungal infections. Vaccination with modified live vaccines may also cause a reactive lymphocytosis about a week after vaccination. Lymphocytes appear slightly enlarged with a dark basophilic cytoplasm
3. Neoplastic (see leukemic disorders below)

B. Lymphopenia
1. Corticosteroids (exogenous or endogenous) decrease lymphocytes. Lymphopenia should resolve within a few days of discontinuing corticosteroids
2. Infectious agents may cause lymphoid tissue destruction (FeLV, FIV, parvovirus, distemper virus), resulting in lymphopenia
3. Lymphatic injury such as in chylothorax, lymphangiectasia, or protein-losing enteropathy causes loss of lymph fluid and lymphopenia
4. Congenital lymphopenia occurs in basset hounds and is associated with severe bacterial infections

VII. Mastocytosis
A. Occurs secondary to mast cell tumors
B. Bone marrow is rarely invaded by mast cells

PLATELET DISORDERS

I. Thrombocytopenia
A. Immune-mediated injury (see below under immune disorders)
B. Increased platelet consumption or utilization
1. Infectious agents such as *E. canis*, *E. ewingii*, *Anaplasma platys*, and *A. phagocytophilum*
2. Canine distemper virus vaccination causes transient thrombocytopenia about a week after vaccination and may persist for several weeks

3. Hemorrhage
4. DIC associated with infection, neoplasia, heartworm disease, pancreatitis, and shock

C. Sequestration of platelets by an enlarged spleen
D. Decreased platelet production
1. Congenital thrombocytopenia may be associated with cyclic hematopoiesis in collies
2. Infectious diseases such as distemper virus, parvovirus, FeLV, and *E. canis*
3. Drugs such as cisplatin, cyclophosphamide, chlorambucil, doxorubicin, and hydroxyurea

II. Thrombocytosis
A. Physiologic thrombocytosis occurs during heavy exercise or from epinephrine release
B. Reactive thrombocytosis
1. From acute blood loss, iron deficiency anemia, trauma, surgery, inflammation, splenectomy, hyperadrenocorticism
2. Tumors causing thrombocytosis include mast cell tumors, hemangiosarcoma, osteosarcoma, lymphoid leukemia, and myeloid leukemia
3. Vincristine administration can cause thrombocytosis
4. Pseudohyperkalemia may be observed due to leakage of potassium from clotted platelets

C. Neoplastic (see leukemic disorders below)

DYSPLASTIC DISORDERS

I. Congenital dysplasia
A. Inherited erythrocyte macrocytosis in miniature and toy poodles
1. Macrocytosis and megaloblastosis with no signs of anemia
2. Not responsive to folate or vitamin B_{12}

B. Inherited macroplatelets in Cavalier King Charles spaniels

II. Infectious causes
A. Typically from FeLV or FIV
B. Dysplastic changes include macrocytosis, megaloblastosis, large hypersegmented neutrophils, and small megakaryocytes
C. Cytopenia may occur

III. Drug-induced
A. Drugs such as chloramphenicol, vincristine, cyclophosphamide, and azathioprine can cause dyserythropoiesis with macrocytosis, nuclear fragmentation, sideroblastosis, megaloblastoid changes, and siderocytosis
B. Changes are not associated with folate deficiency, and normal morphology returns a few days after drug therapy is stopped

IV. Nutritional
A. Malabsorption of vitamin B_{12} in giant schnauzers causes erythroid dysplastic changes with neutrophilic hypersegmentation
B. Folate deficiency
1. Neoplasia, intestinal malabsorption, liver disease can cause folate deficiency, resulting in a macrocytic nonregenerative anemia
2. Anticonvulsants and some antibiotics and antineoplastic agents can inhibit folate metabolism, causing megaloblastic changes in erythroid precursors

LEUKEMIC DISORDERS

I. Lymphoid leukemia
A. Acute lymphoblastic leukemia (ALL)
1. Abnormal proliferation of immature lymphoblasts in bone marrow or blood
2. Rapidly progressive with poor response to therapy
3. Clinical signs include fever, abdominal pain, anorexia, splenomegaly, and pale mucous membranes
4. Most have leukocytosis with abnormal lymphocytes. About 10% have aleukemic leukemia, which is bone marrow involvement without peripheral blood involvement
5. Cytochemical stains may be necessary to differentiate from other forms of leukemia
6. Poor prognosis

B. Chronic lymphocytic leukemia (CLL)
1. Abnormal proliferation of mature lymphocytes in bone marrow or blood
2. Clinical signs include lethargy, inappetance, polyuria, polydipsia, intermittent lameness, and episodes of collapse
3. Most have normocytic, normochromic, nonregenerative anemia with thrombocytopenia. About one third of dogs have hyperproteinemia, many with monoclonal gammopathies. Bence-Jones protein in the urine indicates B-cell origin, but most cases of CLL are of T-cell origin
4. Treat if symptomatic, if there are significant cytopenias, or if lymphadenopathy or splenomegaly are present. Treat with prednisone and chlorambucil
5. Prognosis is better for CLL than for ALL

II. Myeloid malignancy
A. Myelodysplastic syndrome
1. Persistent cytopenia in one or more hematopoietic cell lines, accompanied by abnormal maturation. Associated with FeLV in cats
2. Clinical signs include lethargy resulting from anemia, hemorrhage, and chronic infections
3. Bone marrow is hypercellular with mild increase in myeloblasts. Cells have dysplastic changes, including macrocytosis, megaloblastosis, nuclear fragmentation, abnormal granulation, hypersegmentation or hyposegmentation, micromegakaryocyte or macrothrombocyte formation, and cell giantism
4. Treat supportively. May respond to prednisone and erythropoietin

B. Acute myeloid leukemia (classified as M_1 to M_7, depending on which blast cells predominate in the bone marrow)
1. Acute myeloblastic leukemia (M_1, M_2)
a. Relatively common; often associated with FeLV in cats
b. Severe nonregenerative anemia, thrombocytopenia with leukocytosis
c. Leukemic cells have pale basophilic cytoplasm containing small, red granules

d. Blast cells are variably positive for peroxidase, Sudan black B, chloroacetate esterase, leukocyte alkaline phosphatase, and acid phosphatase with cytochemical staining

2. Acute myelomonocytic (M_4)
 a. Common form involving the stem cell for both granulocytes and monocytes
 b. Both monoblasts and myeloblasts are observed with cytochemical staining
3. Acute monocytic (M_5)
 a. Increased monoblasts in bone marrow. Cells have a basophilic cytoplasm without granulation, and irregular nuclei with prominent nucleoli
 b. Cytochemical staining is positive for nonspecific esterase and acid phosphatase
4. Erythroleukemia (M_6)
 a. Associated with FeLV in cats
 b. Rubriblasts may predominate. Megaloblastosis, neutrophil giantism, or hypersegmentation may also be present
 c. Nucleated RBCs and normochromic macrocytes are observed
5. Megakaryoblastic (M_7)
 a. Rare. May be associated with radiation in the dog
 b. Severe nonregenerative anemia, leukopenia, and variable platelet count
 c. Megakaryoblasts appear in circulation, and platelets may be giant and have abnormal granulation
 d. Immunocytochemical stains are helpful

C. Chronic myeloproliferative diseases
1. Chronic granulocytic (neutrophilic) leukemia
 a. Increased numbers of progranulocytes to metamyelocytes in blood and bone marrow. Myeloblasts in the bone marrow are decreased
 b. Leukocytes are markedly elevated, with mild to moderate anemia
 c. Differentiate from highly suppurative infections such as pyometra that cause a leukemoid reaction
2. Eosinophilic leukemia
 a. Rare. Has been associated with FeLV in the cat
 b. High eosinophil count with immature forms. May appear similar to hypereosinophilic conditions (e.g., allergies, parasites)
 c. Eosinophils infiltrate lymph nodes, liver, and spleen
3. Basophilic leukemia
 a. Rare, mostly in the dog
 b. Mature and immature basophilia in blood or bone marrow. Associated with thrombocytosis and anemia
 c. Must differentiate from mast cell leukemia
 d. Cytochemical staining with ω-exonuclease is helpful
 e. Treat with hydroxyurea

III. Multiple myeloma
A. Plasma cell neoplasm
B. Usually in older dogs; clinical signs include anorexia, listlessness, polyuria, and polydipsia. Lameness is secondary to bone pain. Epistaxis or gingival bleeding occurs secondary to hyperviscosity syndrome or thrombocytopenia
C. Diagnosis
1. Most have monoclonal gammopathy, either IgG or IgA
2. Bence-Jones proteins may be observed in the urine
3. Often associated with nonregenerative, normocytic, or normochromic anemia. Some also have thrombocytopenia
4. About 20% of dogs have hypercalcemia
D. Diagnosis is based on the presence of plasmacytosis, evidence of osteolytic bone lesions, and serum or urine myeloma proteins
E. Differentials for monoclonal gammopathy include ehrlichiosis and benign hypergammaglobulinemia in the dog. Ehrlichiosis, carcinomas, connective tissue disorders, liver disease, and hypersensitivity states are differentials for plasmacytosis
F. Prognosis in the dog is good but poor in the cat
G. Treatment with melphalan and prednisone induces remission in about 90% of dogs

IV. Polycythemia vera
A. Rare
B. Increased hematocrit (PCV 65% to 82%). Blood is hyperviscous, and mucous membranes are dark red
C. Treat with phlebotomy, hydroxyurea, or radiophosphorus

V. Primary thrombocythemia
A. Rare proliferation of platelets
B. Characterized by splenomegaly and platelet function abnormalities (bleeding, thromboembolism)
C. Treat with melphalan, hydroxyurea, or radiophosphorus
D. May transform to chronic myelogenous leukemia

VI. Idiopathic myelofibrosis
A. Uncommon
B. Intramedullary and extramedullary hematopoiesis with reactive or secondary marrow fibrosis
C. Granulocytic and megakaryocytic cells infiltrate the spleen and liver
D. Leukoerythroblastic reaction in which the peripheral blood has both immature granulocytes and erythroid cells. Poikilocytosis and dacryocystosis are present

COAGULATION DISORDERS

I. Diagnostic tests (Figure 17-4)
A. Quick assessment of coagulation
1. Assessment of platelet number on blood smear. Thrombocytopenia is ruled out if under oil immersion there are 7 to 10 platelets per field in the dog and 10 to 15 platelets per field in the cat
2. Activated clotting time
 a. Test of the intrinsic clotting system
 b. Do not sample from the jugular vein because of the risk of hematoma formation
 c. Using a Vacutainer, collect 2 mL of blood into a plain tube, then collect 2 mL into a tube containing siliceous earth. Warm this tube to 37° C before sampling

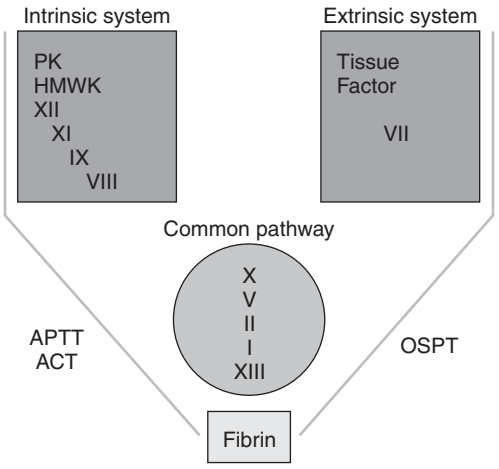


Figure 17-4 The traditional intrinsic, extrinsic, and common coagulation pathways. PK, Prekallikrein; HMWK, high-molecular-weight kininogen; APTT, activated partial thromboplastin time; ACT, activated coagulation time; OSPT, one-stage prothrombin time. (From Nelson RW, Couto CG. *Small Animal Internal Medicine*, 3rd ed. St. Louis, 2003, Mosby.)

d. Immediately invert to mix blood with silaceous activator and place in a 37° C heating block
e. After 45 seconds, remove tube every 5 to 10 seconds and check for clotting. Normal dogs clot within 60 to 120 seconds; normal cats clot within 60 to 70 seconds

3. Bleeding time tests
 a. Buccal mucosa bleeding time test
 (1) May require sedation
 (2) Evert lip, encircle muzzle with gauze to cause the buccal veins to engorge
 (3) Make two parallel incisions in mucosa of upper lip
 (4) Normal dogs and cats stop bleeding from both incisions within 2 to 4 minutes
 (5) Prolonged in those with acquired and inherited platelet dysfunction and von Willebrand disease (vWD). Normal with coagulation factor deficiencies and in some with DIC
 b. Toenail bleeding time test
 (1) Perform only if sedated or anesthetized
 (2) Cut nail at cuticle and allow blood to flow freely
 (3) Normal dogs stop bleeding in 5 to 6 minutes
 (4) Prolonged in significant coagulation factor deficiencies, vWD, platelet dysfunction, and DIC

B. Coagulation screening assays measure the time for fibrin clot formation in vitro
 1. Activated partial thromboplastin time (APTT) detects deficiencies of intrinsic and common coagulation pathways
 2. Prothrombin time (PT) detects deficiencies of extrinsic and common pathways
 3. Fibrinogen concentration measures plasma fibrinogen
 4. Thrombin clotting time (TCT) detects deficiency and dysfunction of fibrinogen
 5. von Willebrand factor (vWF) assay
 a. Specific measurement of vWF concentration
 b. If vWF is below the reference range, the dog is at risk for carrying or expressing vWD
 6. Diagnosis of DIC
 a. Based on clinical signs and coagulation tests
 b. High plasma fibrin, fibrinogen degradation products, or cross-linked fibrin fragments
 c. Decreasing platelet count, low antithrombin activity, prolongation of aPTT, PT, TCT, and presence of schistocytes

II. Coagulation factor deficiencies
 A. Acquired deficiencies are common
 1. Coagulation factors are produced in the liver; conditions decreasing liver function or mass will result in decreased coagulation factors
 2. Vitamin K deficiency occurs with ingestion of anticoagulant rodenticides, posthepatic biliary obstruction, or infiltrative bowel disease. Vitamin K is required for activation of factors II, VII, IX, and X
 3. Heparin inhibits fibrin clot formation by increasing the activity of antithrombin III. Excess heparin results from overdosage in the treatment of thrombotic disorders or from release of heparin from mast cell tumor granules
 4. Increased concentration of fibrin degradation products in DIC can interfere with fibrin clot formation
 B. Inherited deficiencies
 1. Hemophilia is the most severe coagulation factor deficiency
 a. Inherited X-linked recessive trait. Spontaneous mutations causing hemophilia are not uncommon
 b. Males express hemophilia, whereas females are asymptomatic carriers
 c. Hemophilia A is more common and is caused by a defect in the factor VIII gene. Hemophilia B is caused by a defect in the factor IX gene
 d. German shepherd dogs (especially from European stock) have the highest incidence of hemophilia A
 2. Deficiencies of other factors (XI, X, VII, II, fibrinogen) have been described
 3. Factor XII deficiency is common in cats but does not cause bleeding
 4. Combined deficiency of factors II, VII, IX, and X has been reported in Devon Rex cats and Labrador retrievers

III. von Willebrand disease (vWD)
 A. Most common hereditary bleeding disorder in dogs. Occurs in both males and females
 B. Breeds with a high prevalence of vWD include the Doberman pinscher, Scottish terrier, Shetland sheepdog, German wirehaired pointer, German shorthaired pointer, Pembroke Welsh corgi, Chesapeake bay retriever, and Australian shepherd, but it can occur in any breed, including mixed-breed dogs
 C. Bleeding in those with vWD is exacerbated by other underlying conditions such as infection, endocrinopathies, or concurrent thrombocytopenias

D. Three subtypes occur in dogs:
 1. Type 1 vWD is mild to moderate, with low vWF concentration but normal vWF structure
 2. Type 2 vWD causes severe bleeding with low vWF concentration and abnormal vWF structure
 3. Type 3 vWD causes severe bleeding as a result of the complete lack of vWF

IV. Disseminated intravascular coagulopathy (DIC)
 A. Caused by activation of the coagulation cascade. Clot formation leads to thrombosis and occlusion of blood vessels, decreased blood supply to tissues, and activation of fibrinolytic pathways
 B. DIC is usually associated with severe inflammation, sepsis, neoplasia (lymphoma, hepatic neoplasia, hemangiosarcoma, prostatic carcinoma, mammary carcinoma), burn wounds, pancreatitis, and intravascular hemolysis
 C. Bleeding develops as coagulation factors and platelets are consumed in the thrombotic process
 D. Clinical signs include spontaneous hemorrhage or excessive bleeding after surgery or trauma. The presence of petechiae is a common sign of thrombocytopenia. Bleeding is usually severe, and signs of underlying disease are typically present
 E. Diagnosis is through a combination of clinical signs, history, radiography to detect bleeding in body cavities, and laboratory findings, especially elevated fibrinogen degradation products

V. Treatment
 A. Transfusion therapy is necessary to supply coagulation factors in those with severe deficiencies
 1. Stored whole blood or RBCs do not contain replacement levels of coagulation factors or vWF. Fresh whole blood (within 4 to 6 hours of collection) will supply coagulation factors, but there is a higher risk of transfusion reactions
 2. Transfusion of plasma products along with stored whole blood or packed RBCs is the equivalent to fresh whole blood, and this combination reduces the risk of transfusion reactions
 3. Do not treat with antihistamine or corticosteroids before transfusion of blood products
 4. In cats, use blood products that are blood type and crossmatch compatible
 5. In dogs, use dogs negative for dog erythrocyte antigen (DEA) 1 and DEA 7 as "universal donors"
 B. Provide supportive care to minimize the risk of hemorrhage. Do not give sulfas or NSAIDs that can cause platelet inhibition
 C. Drug therapy
 1. Treat any underlying disorder that may impair clotting ability (hyperestrogenism, hypothyroidism, hyperadrenocorticism)
 2. Vitamin K therapy is only useful if there is vitamin K deficiency
 a. The most common cause of vitamin K deficiency is anticoagulant rodenticide toxicity
 b. Warfarin is short-acting, and treatment for about 1 week is usually adequate. Treat with subcutaneous vitamin K_1, followed by oral vitamin K_1
 c. Long-acting anticoagulants (such as brodifacoum) require treatment for 4 to 6 weeks
 3. Desmopressin acetate may improve hemostasis in some dogs with vWD
 4. Heparin therapy is typically used to treat thrombotic DIC. Close monitoring is required

IMMUNE DISORDERS

I. Immune-mediated hemolytic anemia (IMHA)
 A. Cause is unknown
 B. Breeds with a higher incidence include cocker spaniels, poodles, and old English sheepdogs. Vaccination, stress, or infection may trigger IMHA
 C. Clinical signs include weakness, collapse, pale gums, discolored urine, fever, hepatosplenomegaly, tachycardia, and tachypnea
 D. Laboratory findings include anemia, reticulocytosis, spherocytosis, and leukocytosis with left shift. Coombs' test is usually positive. Liver enzymes may be elevated as a result of hypoxic damage. Spontaneous autoagglutination of RBCs may occur (Figure 17-5)
 E. DIC and thromboembolism are complications
 F. Test cats for FeLV, FIV, and hemoplasmosis
 G. May occur in conjunction with immune-mediated thrombocytopenia
 H. Treatment
 1. Intravenous (IV) fluids and blood transfusion if PCV is below 15%
 2. Prophylactic therapy with heparin or aspirin to prevent thromboembolism
 3. In mild cases, treatment with prednisone or prednisone + azathioprine
 4. Cases in which bilirubin is greater than 3 mg/dL or the PCV is rapidly dropping require aggressive therapy. Treat with IV fluids, heparin, prednisone, and azathioprine. Human immunoglobulin and cyclosporine can also be used

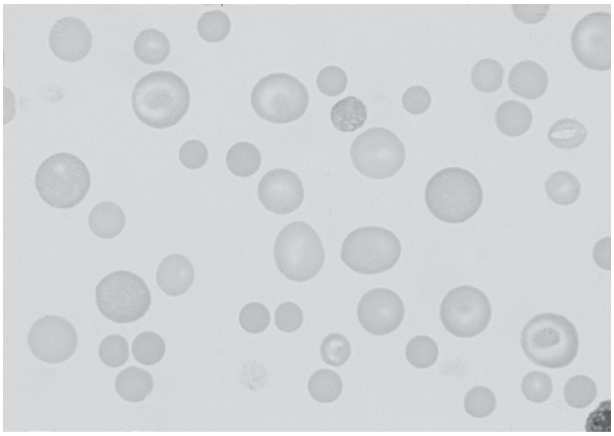


Figure 17-5 A blood smear from a dog with immune-mediated hemolytic anemia. Note the marked anisocytosis resulting from a mixed population of small spherocytes and large, immature, and normal red blood cells. The spherocytes are dense staining and lack central pallor. A few polychromatophils are in the shape of codocytes. (Wright's stain, original magnification 250×.) (From Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St. Louis, 2008, Mosby.)

5. Monitor CBC daily until stable, then weekly until PCV is greater than 25%. Treat for a minimum of 6 months

I. Prognosis is fair for mild cases and guarded for severe cases. Relapses occur unpredictably

II. Immune-mediated thrombocytopenia (IMT)
- A. Cause is unknown. IMT is suspected when a "healthy" animal presents with petechiae or mucosal bleeding
- B. Clinical signs include epistaxis, oral cavity bleeding, petechiae or ecchymoses, hematuria, melena, pale gums, splenomegaly, fever, or retinal hemorrhage
- C. Diagnosis is by finding severe thrombocytopenia (i.e., less than 25,000/μL) in a healthy appearing animal
 1. If platelets number more than 25,000/μL, consider other causes
 2. Chemistry and coagulation profiles are usually normal. There may be a mild elevation of fibrin degradation products due to hemorrhage
- D. May occur in association with IMHA
- E. Treatment
 1. Treat most cases with prednisone or prednisone + azathioprine
 2. Vincristine can be used once to help elevate the platelet count
 3. Do not use cyclophosphamide
 4. Monitor platelet counts daily until greater than 25,000/μL, then weekly. Treat for a minimum of 6 months
- F. Prognosis is guarded until the platelet count begins to rise. Relapses occur unpredictably

III. Systemic lupus erythematosus (SLE)
- A. Antibodies are produced against nuclear, cytoplasmic, and cell membrane molecules; these antibodies directly damage tissues through the formation of immune complexes
- B. Clinical signs are varied since almost any organ can be affected in SLE
 1. Immune-mediated polyarthritis is most commonly recognized in combination with immune-mediated skin disease, glomerulonephritis, hemolytic anemia, or thrombocytopenia
 2. Skin signs include erythema, scaling, crusting, depigmentation, and alopecia. Skin and oral ulcers may occur
- C. A positive antinuclear antibody (ANA) test with two manifestations of autoimmunity or three manifestations of autoimmunity with negative ANA supports a diagnosis of SLE
- D. Treatment
 1. Avoid exposure to sunlight, which may exacerbate SLE
 2. Lameness can be treated with NSAIDs (carprofen, etodolac, or meloxicam)
 3. More severe signs are treated with corticosteroids or corticosteroids + azathioprine. Treat for a minimum of 6 months
- E. Prognosis is usually good, although signs may wax and wane. Patients should be monitored for the development of renal disease

SPLENIC DISORDERS

I. Anatomy and function
- A. Located in the left cranial abdomen attached to the greater curvature of the stomach. The canine spleen is sinusoidal, whereas the cat spleen is nonsinusoidal
- B. The primary function of the spleen is filtration of peripheral blood. RBCs and other circulating cells are removed as they age, and inclusions are removed from the RBCs. Inclusions removed include Howell-Jolly bodies, Heinz bodies, and hemoparasites
- C. The spleen has an important immunologic function as it is the largest lymphoid organ in the body
 1. The marginal zone of the white pulp contains both B and T lymphocytes, whereas most of the B cells are in the germinal center and mantle zones. If antigen is present on lymphocytes, they undergo activation and proliferation
 2. Important in defense against polysaccharide-encapsulated bacteria and other circulating particulate antigens
 3. Surface immunoglobulins on RBCs are removed by splenic macrophages
- D. Reservoir function
 1. Blood cells are stored in the spleen, and the spleen is capable of holding a large volume of blood
 2. The spleen normally stores about 10% to 20% of the total blood volume, but it can hold up to a third of the dog's RBCs
- E. Hematopoietic function
 1. The normal adult spleen has no hematopoietic capacity, but the red pulp retains the ability for extramedullary hematopoiesis (EMH) if needed
 2. Disorders associated with EMH include hemangiosarcoma, lymphoma, multiple myeloma, leukemia, IMHA, eosinophilic gastroenteritis, estrogen-induced bone marrow hypoplasia, pyometra, and ehrlichiosis
 3. EMH is not as common in cats as in dogs
 4. With EMH, immature red and white cell precursors may be present in the peripheral blood
- F. Other functions of the spleen include storage and activation of factor VIII, formation and degradation of angiotensin-converting enzyme, modulation of norepinephrine concentrations and prostaglandin E_2 activity, and iron storage and recycling of iron to bone marrow

II. Causes
- A. Localized splenomegaly
 1. Primary or metastatic neoplasia
 a. Hemangiosarcoma is the most common neoplasm in the spleen of the dog. Hemangiomas also occur. Breeds at higher risk for hemangiosarcoma of the spleen include German shepherd dogs, golden retrievers, and Labrador retrievers
 b. In cats, systemic mastocytosis and lymphoma are the most common splenic tumors

c. Other tumors in the spleen include the sarcomas, histiocytoma, lipoma, mesenchymoma, and lymphoma. Metastatic carcinomas are rare
2. Nodular hyperplasia
a. Single or multiple nodules that are benign accumulations of lymphoid cells, hematopoietic cells, and plasma cells
b. Common in older dogs
3. Hematoma from trauma, causing a mass that cannot be differentiated from neoplasia on morphology
4. Abscesses are rare but may occur from hematogenous spread of bacteria (especially *Staphylococcus* in the dog). In the cat, abscess has been associated with cholangiohepatitis

B. Generalized splenomegaly
1. Inflammatory or infectious disease
a. Causes of suppurative inflammation include bacterial endocarditis, septicemia, splenic torsion, migrating foreign body, penetrating abdominal wounds, toxoplasmosis, mycobacteriosis, and infectious canine hepatitis
b. Causes of necrotizing inflammation include splenic torsion, splenic neoplasia, infectious canine hepatitis, and salmonellosis
c. Causes of lymphoplasmacytic inflammation include chronic infectious canine hepatitis, ehrlichiosis, Rocky Mountain spotted fever, pyometra, brucellosis, and hemobartonellosis
d. Causes of granulomatous inflammation include histoplasmosis, mycobacteriosis, and leishmaniasis, and causes of pyogranulomatous inflammation include blastomycosis, sporotrichosis, and feline infectious peritonitis
2. Hyperplastic splenomegaly
a. Common in immune-mediated diseases, including IMHA and IMT
b. Also common in dogs with bacterial endocarditis and chronic bacteremia. Also associated with SLE
3. Congestive splenomegaly
a. Can occur as a result of smooth muscle relaxation in the splenic capsule, especially by phenothiazine and barbiturates. Up to 30% of blood may pool in the spleen
b. Right-sided congestive heart failure, caudal vena cava obstruction, and intrahepatic obstruction can cause splenic congestion
c. Splenic torsion results in marked splenomegaly, and may be associated with gastric dilatation-volvulus
4. Infiltrative diseases include hypereosinophilic syndrome of cats and splenic amyloidosis. EMH is common in dogs but rarely causes splenomegaly

C. Hypersplenism can be primary or secondary to an underlying disease. Characteristics include splenomegaly with cytopenia that resolves with splenectomy
D. Hyposplenism is a decrease in splenic function. Characteristics include target cells, acanthocytes, Howell-Jolly bodies, nucleated RBCs, reticulocytosis, and thrombocytosis

III. Clinical signs
A. Signs are nonspecific and related to the underlying disease process
B. Signs include weight loss, anorexia, weakness, vomiting, diarrhea, abdominal distension, polyuria, and polydipsia. Collapse with pale mucous membranes suggests splenic rupture

IV. Diagnosis
A. History
1. Intermittent collapse and pale mucous membranes suggest hemangiosarcoma
2. Acute abdominal distention may suggest torsion
3. Tick exposure suggests ehrlichiosis or Rocky Mountain spotted fever
B. Physical examination
1. The spleen is normally palpable in many dogs and cats. The position of the spleen can vary by breed, body weight, and food in the stomach
2. Lymphadenopathy may suggest lymphoma, leukemia, or infectious diseases
C. Hematology and serum biochemistry may suggest the underlying disorder
D. Diagnostic imaging
1. On radiography, rounded or blunted margins are characteristic of enlargement. A mid-abdominal mass on a lateral view abdominal radiograph is most likely a splenic mass
2. Ultrasound is useful for determining size, location, and presence of masses. The spleen is normally hyperechoic
E. Fine needle aspiration (FNA) is most useful in diffuse splenic disease and should be performed with ultrasound guidance. FNA should not be performed in those with suspected hemangiosarcoma or if there is a large cavitary lesion
F. Needle biopsy is also used for diffuse splenic disease

V. Treatment
A. Splenectomy is indicated in splenic rupture, splenic torsion, or splenic masses
B. In cats, splenectomy prolongs life expectancy in systemic mastocytosis
C. With hemangiosarcoma there is a high risk of rupture, so splenectomy should be performed
D. Splenectomy is not recommended in IMHA or IMT except as a last resort
E. In some patients with lymphoma and leukemia, splenectomy may be an option
F. Treat the underlying disease process

Supplemental Reading

Brooks MB. Coagulation diseases. In Brichard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 256-264.

Cowell RL, Tyler RD, Meinkoth JH, DeNicola DB. *Diagnostic Cytology and Hematology of the Dog and Cat*, 3rd ed. St Louis, 2008, Mosby.

Kisseberth WC, McEntee MC. Diseases of the spleen. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 272-282.

Raskin RE. Erythrocytes, leukocytes, and platelets. In Brichard SF, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 231-255.

Stone M. Systemic immune-mediated diseases. In Brichard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 265-271.

Thrall MA, ed. *Veterinary Hematology and Clinical Chemistry*. Philadelphia, 2004, Lippincott Williams & Wilkins.

Vail DM. Lymphoid neoplasia. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 292-300.

Villiers E, Blackwood L. *BSAVA Manual of Canine and Feline Clinical Pathology*. Gloucester, UK, 2005, BSAVA.

Willard MD, Tvedten H. *Small Animal Clinical Diagnosis by Laboratory Methods.* St Louis, 2003, Saunders.

18 CHAPTER

Infectious Diseases

Patricia A. Schenck

FELINE LEUKEMIA VIRUS

I. Causes
 A. Structure of the virus
 1. RNA retrovirus
 2. Core contains viral RNA and reverse transcriptase enzyme
 3. Core protein p27 is the specific antigen detected by diagnostic tests
 4. Envelope glycoprotein (gp70) is important in defining the antigenic subgroup; only subgroup A is infectious
 5. Envelope protein p15e mediates feline leukemia virus (FeLV) immunodeficiency
 B. Prevalence
 1. Young kittens (i.e., younger than 4 months of age) are most susceptible
 2. Highest prevalence in free-roaming stray cats
 C. Transmission
 1. Primarily through saliva. Infected queens shed virus in milk. Exposure is typically by direct contact through grooming, bite wounds, and sharing of food and water bowls
 2. Transplacental transmission can occur
 3. FeLV survives a maximum of 48 hours in the environment and is readily destroyed by most disinfectants

II. Pathogenesis
 A. Sequence of FeLV infection
 1. After entry, FeLV replicates in lymphoid tissue throughout the body. Enzyme-linked immunosorbent assay (ELISA) tests may detect antigen in the blood at this stage. If an immune response is effective, the infection may be eliminated
 2. FeLV infects bone marrow, causing circulation of infected leukocytes and platelets. These are detectable with immunofluorescent antibody (IFA) testing and indicate that the infection will be persistent
 3. FeLV infects glandular cells, and virus is shed in body secretions. At this stage, infected cats are contagious
 B. Many cats over 4 months of age resist infection
 C. Most exposed cats develop a transient infection that is rejected by an immune response. These cats eliminate virus within 4 to 6 weeks after infection. Vaccinated cats will have a brief transient infection but resist persistent infection
 D. Some cats that recover from transient infection become latent carriers of FeLV. The latent stage is usually eliminated with time, but a few remain infected. In latent carriers, there is the rare possibility that FeLV may be reactivated to replicating infection
 E. Persistent infection is eventually fatal

III. Clinical signs
 A. The immunosuppression effects of FeLV cause many nonspecific clinical signs, including weight loss, fever, dehydration, anemia, diarrhea, stomatitis, lymphadenopathy, and oculonasal discharge
 B. FeLV can be a primary cause of lymphoma, including alimentary, mediastinal, multicentric, renal, ocular, neural, and cutaneous lymphoma. Lymphoid leukemia, nonlymphoid leukemia, or myelodysplasia may result from bone marrow infection
 C. Nonregenerative anemia is common with FeLV. FeLV-related neutropenia or thrombocytopenia may occur
 D. Secondary infections are common and include viral, fungal, protozoal, *Mycoplasma*, and bacterial causes
 E. Peripheral lymph node hyperplasia can be seen, especially in young adult cats. This tends to resolve but may recur or develop into lymphoma at a later date
 F. Immune-mediated disorders such as immune-mediated hemolytic anemia, immune-mediated thrombocytopenia, immune-complex glomerulonephritis, polyarthritis, pemphigus, and systemic lupus erythematosus like syndrome may occur
 G. Infected queens may have reproductive failure. Infertility, fetal resorption, abortion, stillbirth, fading kitten syndrome, and milk-borne transmission can occur

IV. Diagnosis
 A. Test all cats before vaccination and before bringing a new cat into the house or cattery
 B. ELISA and immunochromatographic tests
 1. Rapid screening tests; detect infection earlier than IFA tests
 2. Detect FeLV p27 antigen (a viral core protein); test not affected by vaccination or maternal antibodies
 3. Confirm positive results with repeat testing in several weeks

C. The IFA test is preferred for confirmation of FeLV because it is more specific than ELISA testing
 1. May be negative in early infections
 2. Confirm positive tests with repeat testing in a month
D. Polymerase chain reaction (PCR) testing detects FeLV nucleic acid in blood, bone marrow, or biopsies and may be helpful in detecting latent FeLV infection
E. Virus isolation is the "gold standard" for confirming positive test results with other methods

V. Treatment
A. Provide good general health care and prevent spread of infection to noninfected cats
B. Zidovudine (AZT) and interferon therapy may have some effectiveness
C. Provide fluid therapy, nutritional support, antibiotics as needed

VI. Prevention and control
A. Vaccination
 1. Vaccines are available but are considered "non-core" vaccines
 2. Vaccinate cats that go outdoors or negative cats living in a household with infected cats
 3. Vaccination is not recommended in adult indoor cats with no exposure to infected cats
 4. Local swelling may develop at the site of vaccination and can develop into vaccine-associated sarcomas at a later date
 5. Vaccination is not 100% effective
B. Control in multi-cat households and catteries
 1. In catteries with FeLV-positive cats, follow a test and removal program to eliminate FeLV from the household
 2. In FeLV-negative households or catteries, screen any new cats with ELISA testing, vaccinate (if negative), and isolate for 3 months

FELINE IMMUNODEFICIENCY VIRUS (FIV)

I. Causes
A. Lentivirus subfamily of retrovirus; RNA virus with outer envelope and nuclear capsid. Subtype A is common in the western United States; subtype B is common in the eastern United States
B. Epidemiology
 1. Prevalence is higher in free-roaming stray cats
 2. Affects all ages but most prevalent in cats 6 years of age or older
 3. More prevalent in male cats
 4. Wild felids are susceptible to feline immunodeficiency virus (FIV)
C. Transmission
 1. Shed in saliva; most infection occurs via a bite wound
 2. Can be transmitted via intravenous (IV) transfusion of contaminated blood
D. Pathogenesis
 1. Infects T lymphocytes with loss of CD4+ lymphocytes, inversion of the CD4-CD8 ratio with loss of CD8+ cells later
 2. Latent period can last for years
 3. Progressive loss of T cells results in an immunodeficiency syndrome with recurrent infections
 4. Eventually fatal

II. Clinical signs
A. Initial infection occurs within 4 to 6 weeks after exposure; signs are usually mild and include a transient fever, neutropenia, lymphopenia, and lymphadenopathy
B. A latent period follows, usually for several years
C. An immunodeficiency syndrome follows that predisposes the cat to chronic and recurrent infections
 1. General signs include weight loss, wasting, recurrent fever, lymphadenopathy, polyclonal hypergammaglobulinemia, recurrent anemia, leucopenia, or thrombocytopenia
 2. Chronic infections affect the oral cavity (common), respiratory tract, gastrointestinal (GI) tract, urinary tract, and skin. In the mouth, lesions often begin in the fauces and spread along the maxillary gingivae
 3. Common conditions include calicivirus, herpesvirus, poxvirus, papillomavirus, *Chlamydophila felis*, *Mycoplasma haemofelis*, *Staphylococcus*, *Pseudomonas*, *Mycobacterium*, *Yersinia*, *Candida*, *Cryptococcus*, *Aspergillus*, *Toxoplasma*, *Giardia*, *Cryptosporidium*, *Demodex*, and *Notoedres* spp.
 4. FIV is neurotropic leading to neuronal damage; signs include dementia, behavior abnormalities, circling, gait abnormalities, and abnormal reflexes
 5. B-cell lymphoma and myeloproliferative neoplasia occur more frequently in FIV-infected cats
 6. Ocular disorders (anterior uveitis, chorioretinitis, glaucoma, retinal hemorrhage, retinal degeneration) and nephropathy may occur in association with FIV

III. Diagnosis
A. Test cats over 6 months of age
B. Assays for antibody
 1. The ELISA antibody test is useful for screening. Confirm any positive ELISA results with Western blot
 2. IFA test
 3. The Western blot test detects antibodies against viral proteins and is the "gold standard" test for confirming FIV
C. Commercial PCR assays are unreliable at this time

IV. Treatment
A. Specific antiviral therapy
 1. AZT can be used; however, it is myelosuppressive. Drug-resistant strains may emerge
 2. Treatment with feline or human interferon can be attempted but is expensive and may only be effective short-term
B. General supportive therapy includes antibiotics, fluid therapy, and nutritional support. Use metronidazole and clindamycin to treat stomatitis

V. FIV-positive cats can live several years before exhibiting clinical signs

VI. Prevention
A. Prevent exposure to other potentially infected cats

1. Spay and neuter cats that go outdoors to minimize fighting
2. Minimize exposure to stray cats

B. Keep infected cats indoors to prevent exposure to noninfected cats

C. A killed vaccine is available that contains subtypes A and D; it is unknown whether there is cross-protection with other subtypes. FIV vaccination is not recommended as a core vaccine

D. Before vaccination, make sure that the cat is FIV antibody negative

FELINE INFECTIOUS PERITONITIS (FIP)

I. Causes

A. Feline coronavirus (FCoV), a single-stranded enveloped RNA virus that infects cells of the respiratory and GI tracts

B. Pathogenesis

1. Feline infectious peritonitis (FIP) occurs when the enterotropic FCoV mutates, which allows FCoV to infect and replicate in macrophages
2. Macrophages carry the mutated virus to peritoneum, pleura, kidney, uvea, and nervous system
3. It is the immune reaction to the virus that causes disease

II. Epidemiology

A. Seroprevalence for FCoV is high, yet few cats develop FIP. Prevalence is highest in catteries and shelters

B. Risk factors

1. Young cats (6 months to 3 years) are at increased risk of FIP
2. Cats in catteries, shelters, or multiple cat households are at higher risk of FIP
3. Anything that causes an increased replication of FCoV in the intestine (stress, concurrent disease, corticosteroids, immuno suppression, surgery) increases the probability of virus mutation
4. Most wild felids (e.g., lions, cougars, cheetahs, jaguars) are susceptible to FCoV and FIP. Cheetahs are particularly susceptible to FIP
5. Genetics may play a role in the susceptibility to FIP

C. Transmission is through oronasal contact with infected feces

1. FCoV can survive for 7 weeks in dried feces; thus contaminated articles (e.g., dishes, shoes, clothing) can serve as fomites. Most disinfectants will destroy FCoV
2. Carriers of FCoV can shed virus in feces for 10 months
3. Cats with FIP shed the nonmutated form of FCoV

III. Clinical signs

A. Incubation period is variable from a few weeks to several years. The onset is usually gradual but may be acute in young kittens

B. Once clinical signs develop, FIP is progressive and fatal usually within 3 to 6 weeks but may result in prolonged illness for 6 months or longer

C. Effusive (wet) form of FIP

1. Inflammatory fluid is predominantly in the abdominal cavity but can also be present in the thoracic cavity
2. Effusion in the peritoneal cavity causes progressive fluid distension, which can be detected by palpation and percussion of a fluid wave. Scrotal swelling may be present in intact males
3. Thoracic effusion causes dyspnea, tachypnea, and exercise intolerance from compression by fluid in the pleural space. Muffled heart sounds are usually noted
4. Thoracic and abdominal effusion can be confirmed by radiography
5. Pericardial effusion also occurs but does not typically cause clinical signs

D. Noneffusive (dry) form of FIP

1. Characterized by pyogranulomatous inflammation and necrotizing vasculitis in multiple organs. The specific organs affected determine which clinical signs are present
2. Organs affected include kidney, liver, spleen, visceral lymph nodes, uvea, retina, brain, lungs, and testicles
3. Meningoencephalitis and myelitis are common. The most common clinical signs are ataxia, tremors, vestibular dysfunction, seizures, paresis, and behavioral changes. Hydrocephalus can occur

IV. Diagnosis of FIP

A. Hematology and serum chemistries

1. Total serum protein and globulins are increased in most cases; albumin is commonly decreased. A decreased serum albumin globulin ratio (A:G < 0.8) strongly suggests FIP
2. Chemistry profiles may reveal a number of abnormalities depending on the organs affected

B. Radiology is useful for confirming the presence of thoracic and abdominal effusions

C. Fluid analysis of effusions

1. If total fluid protein is greater than 3.5 g/dL with more than 50% globulins, FIP is likely
2. FIP fluid usually has a low nucleated cell count
3. Cellular analysis of FIP fluid shows a pyogranulomatous exudate
4. Fluid may be stringy or sticky and may clot when refrigerated

D. Cerebrospinal fluid has a high protein concentration and an elevated nucleated cell count

E. FCoV antibody titers in serum or effusions

1. If the titer is positive but low, FIP is possible (if clinical signs are present)
2. If the titer is positive and high, FIP is probable (if clinical signs are present)
3. If the titer is negative, FIP is unlikely
4. Avoid rapid in-office ELISA tests that do not give titer information

F. The reverse transcriptase-polymerase chain reaction (RT-PCR) test can detect FCoV in blood, effusions, tissues, or feces. This indicates the presence of FCoV but does not distinguish between the mutated (FIP) form and the nonmutated form

G. Histopathology is definitive for confirmation of FIP. Lesions of vasculitis and pyogranulomatous inflammation are characteristic. FCoV can be identified in tissue specimens by PCR and IFA
H. Immunofluorescence and immunohistochemistry of tissue samples or effusion are definitive for effusive FIP

V. Treatment
A. No treatment has been proven to reduce the risk of FIP development in cats with FCoV
B. Antiviral drugs and immunomodulators have not been successful
C. Interferon therapy may cause remission in some, but is very expensive
D. Supportive care with high-dose corticosteroid with or without cytotoxic alkylating agents (chlorambucil, cyclophosphamide) may cause transient improvement

VI. Prevention
A. A vaccine is available but has not been shown to be effective and is not recommended
B. Control of exposure
1. Use good husbandry practices, reduce stress, avoid overcrowding, clean litter daily, and disinfect feeding and water bowls
2. Do not breed cats that have produced kittens that later developed FIP because of the possibility of genetic susceptibility
3. Wean kittens and remove them from the mother by 5 to 6 weeks of age. Isolate from all other cats until at least 4 months old
4. Any cat that tests positive for FCoV can shed virus in the feces and has the potential for developing FIP

FELINE INFECTIOUS RESPIRATORY DISEASE

I. Causes
A. Viruses: Feline herpesvirus-1 (FHV, feline viral rhinotracheitis, FVR), feline calicivirus (FCV)
B. Bacteria: *Chlamydia felis, Bordetella bronchiseptica, Mycoplasma felis*

II. Transmission
A. Via aerosol infection, through direct contact or fomites
1. FHV survives about 24 hours outside the host and is susceptible to drying and most disinfectants
2. FCV survives 8 to 10 days outside the host; bleach is the preferred disinfectant
B. Cats that have recovered from FHV and FCV become subclinical carriers, shedding virus for long periods of time
1. FHV persists for life, and carriers shed virus intermittently for approximately 2 weeks
2. FCV is shed for months to years
3. *Chlamydophila felis* can be shed for up to 18 months
4. *Bordetella bronchiseptica* can be shed for up to 5 months

III. Clinical signs
A. General signs include sudden onset of naso-ocular discharge, with anorexia, fever, and depression. Signs may be severe in young kittens. Infection with FHV and FCV is typically self-limiting within 10 days
B. FHV attacks conjunctival, nasal, and laryngotracheal epithelium, causing sneezing, lacrimation, naso-ocular discharge, coughing, and excess salivation
1. Secondary bacterial infection can occur
2. Turbinate damage may cause obstruction
3. Ulcerative lesions are not common
4. Abortion may occur in infected pregnant cats. Newborn kittens may have fatal encephalitis or hepatitis. Neonates may develop panophthalmitis, resulting in permanent ocular damage
C. Calicivirus consistently produces oral ulcers
1. Nasal crusting and ulceration may be seen
2. Mild rhinitis and conjunctivitis are commonly seen
3. Other signs associated with FCV include synovitis, fever, joint pain, enteritis, lower urinary tract disease
4. An acute hemorrhagic fever syndrome may occur with high fever, respiratory signs, ulcerative dermatitis, pulmonary edema, abdominal effusion, hepatic necrosis, disseminated intravascular coagulopathy (DIC), vomiting, diarrhea, epistaxis, or jaundice. Mortality is high, and FCV vaccines do not appear to protect against this strain
D. *Chlamydia felis* causes chronic conjunctivitis. Nasal discharge, sneezing, or pneumonia is uncommon
E. *Bordetella bronchiseptica* may cause fatal bronchopneumonia but is usually mild. Coughing does not routinely occur as in dogs
F. Complications
1. Cats that have recovered from FHV and FCV are carriers and are infectious for other cats
2. Chronic nasal disease can occur after FHV infection and includes sinusitis, turbinate damage, and obstructed nasal passages
3. Chronic ocular disease can occur after FHV infection and includes keratoconjunctivitis sicca, ulcerative keratitis, tear duct blockage, conjunctivitis, or anterior uveitis
4. Chronic oral disease such as stomatitis and gingivitis may be linked to FCV infection

IV. Diagnosis
A. The general diagnosis of upper respiratory infection is acceptable for the individual cat with mild infection. If infection is severe, or there is an outbreak of disease in a cattery, a confirmatory diagnosis should be attempted
1. Naso-ocular signs and corneal ulceration are more common with FHV
2. Oral ulcers are more common with FCV
3. Persistent conjunctivitis is common with chlamydophilosis
B. Direct immunofluorescence if most useful for FHV. Virus isolation from swabs is best for confirming FCV. PCR is sensitive for FHV determination

C. *Bordetella, Chlamydia*, and *Mycoplasma* spp. can be identified by culture
D. Intranuclear inclusion bodies (FHV or *Chlamydophila*) may be seen in conjunctival scrapings or biopsy
E. Evaluate for underlying FIV or FeLV if there are recurring episodes or if signs persist longer than 2 weeks

V. Treatment
A. Treat as an outpatient if possible
B. Treat supportively and provide fluid and nutritional support if needed
C. Ophthalmic therapy
1. Topical antiviral drugs can be used to treat ophthalmic signs of FHV
2. Do not use topical corticosteroids in FHV
3. Use tetracycline ophthalmic ointment for 3 to 4 weeks if *Chlamydophila* or *Mycoplasma* spp. are present
D. L-lysine therapy may reduce replication of FHV. Give twice daily with food
E. Broad-spectrum antibiotics (e.g., amoxicillin, doxycycline) can be used to control secondary infections

VI. Prevention
A. Vaccinate for FHV and FCV
B. Intranasal (modified live-virus vaccine [MLV]) vaccines give better protection and avoid adjuvant-related problems (injection site sarcomas). Sneezing and oculonasal discharge are common after intranasal vaccination
C. In shelters, vaccinate and isolate all new cats for 3 weeks. Provide adequate ventilation and disinfection

CANINE INFECTIOUS TRACHEOBRONCHITIS (KENNEL COUGH)

I. Causes
A. Canine parainfluenza virus (CPIV) or *Bordetella bronchiseptica* primarily. Canine adenovirus (CAV-2), herpesvirus, reovirus, and mycoplasmas may play a role
B. Cats may develop respiratory disease from *B. bronchiseptica*
C. Highly contagious, transmitted via aerosolized respiratory secretions or fomites
D. More common in dogs confined in facilities with poor ventilation

II. Clinical signs
A. Acute onset of loud, hacking cough. There is usually an increased production of mucus
B. Serous naso-ocular discharge may be present
C. Dogs typically continue to eat, are nonfebrile and active (unless pneumonia is present)
D. The clinical course is about 7 to 14 days

III. Diagnosis is usually based on history and clinical signs
A. Complete blood cell count(CBC) will typically be normal unless pneumonia is present (neutrophilic leukocytosis with left shift)
B. Thoracic radiography may identify the presence of pneumonia
C. *Bordetella* or *Mycoplasma* spp. may be found on culture
D. Virus (CPIV, CAV-2) can be isolated from nasopharyngeal or tracheal swabs

IV. Treatment
A. Treat as an outpatient if possible. Treat aggressively if pneumonia is present
B. Most cases are treated with doxycycline, amoxicillin, or azithromycin for possible infection with *Bordetella*
C. Do not use antitussives if the cough is productive. If the cough is nonproductive (with no fever or pneumonia), use hydrocodone and butorphanol
D. Corticosteroids can be used for a short period (5 days) to control cough, but do not use if there are any signs of pneumonia
E. Bronchodilators (e.g., theophylline, animophylline) may be used

V. Prevention
A. Vaccinate against CAV-2 and CPIV (MLV vaccines). If at high risk, *Bordetella* vaccination (killed vaccine) may be considered
1. Intranasal vaccines stimulate local immunity, rapid onset of protection, and minimal interference from maternal antibodies
2. Immunity for *Bordetella* lasts for 6 months or less
B. Isolate affected animals, provide proper ventilation (especially in kennels), use disinfectants

VI. Public health. *B. bronchiseptica* may infect immunocompromised humans, but risk is minimal

CANINE DISTEMPER

I. Causes and epidemiology
A. Epidemiology
1. RNA *Morbillivirus* in the *Paramyxoviridae* family
2. Occurs worldwide, with the highest incidence in dogs 2 to 6 months of age
3. *Canidae, Mustelidae* (e.g., ferrets, minks), *Procyanidae* (raccoons), large *Felidae* (e.g., cheetahs, lions, ocelots), bears, pandas, hyenas are all susceptible to canine distemper (CDV)
B. Transmission
1. Inhalation primarily but virus is shed in all secretions and excretions
2. Virus is shed for up to 1 to 2 weeks after recovery
3. CDV does not survive for more than a few days in the environment and is easily killed by disinfectants

II. Pathogenesis
A. The course of the disease is over a 2-week period
B. After infection of the upper respiratory tract, CDV spreads to lymphoid tissues, including liver, spleen, and GI tract (causing severe immunosuppression). Viremia occurs, and the virus is spread to epithelial tissues and the central nervous system (CNS). The outcome depends on the immune response
1. If the immune response is rapid, there is elimination of CDV with complete recovery (by day 14) and no clinical illness
2. If the immune response is partial, signs are mild and recovery occurs. Neurologic signs may develop from CNS localization

3. If the immune response is poor, there is widespread dissemination of the virus, with clinical signs and a high mortality rate

III. Clinical signs are multisystemic
 A. Depression, anorexia, fever
 B. Rhinitis, nasal discharge, cough, tachypnea (due to pneumonia)
 C. Vomiting, diarrhea
 D. Keratoconjunctivitis, retinal atrophy, retinal detachment, blindness
 E. CNS signs include encephalitis, seizures, ataxia, abnormal reflexes, cranial nerve deficits, eye twitching
 F. Enamel hypoplasia of the teeth
 G. Hard pad disease: Nasodigital hyperkeratosis of the nose and foodpads
 H. Cardiomyopathy

IV. Diagnosis is based on clinical signs in unvaccinated young dogs
 A. Lymphopenia is noted early, with neutrophilic leukocytosis occurring later. Intracytoplasmic inclusion bodies may be seen
 B. Radiography of the thorax shows diffuse interstitial pneumonitis, and secondary bronchopneumonia may develop
 C. Analysis of cerebrospinal fluid may show increased cells (primarily lymphocytes), and antibodies to CDV may be noted
 D. Immunoglobulin G (IgG) titer is not beneficial; an IgM titer is suggestive but not diagnostic
 E. Viral antigen can be identified in blood cells or epithelial cells

V. Treatment is symptomatic and supportive
 A. Broad-spectrum antibiotics
 B. Restrict food intake and give antiemetics and antidiarrheals if vomiting or diarrhea is present
 C. If seizures occur, give dexamethasone for CNS edema. Consider anticonvulsant therapy

VI. Prognosis
 A. High mortality rate in young puppies
 B. Neurologic deficits that occur are irreversible

VII. Prevention
 A. Passive immunity is derived from colostrums
 B. Measles vaccine can give partial protection in young puppies between the ages of 4 and 12 weeks
 C. Vaccinate puppies starting at about 6 weeks, and vaccinate every 3 weeks until 12 to 14 weeks of age. Give a booster 1 year later, then every 3 years
 D. Postvaccinal encephalitis has rarely occurred within a few weeks of MLV distemper vaccination, mostly in neonatal puppies

INTESTINAL VIRUSES

I. Canine parvovirus (CPV-2)
 A. Cause and epidemiology
 1. Nonenveloped, single-stranded deoxyribonucleic acid (DNA) virus
 2. Probably evolved from feline panleukopenia virus
 3. Transmission is fecal-oral
 a. Massive amounts of virus are shed in feces, and the virus can survive for 5 to 7 months in the environment. Thus environmental contamination is a major source of infection
 b. Signs of infection appear about 4 to 7 days after exposure
 c. Clinical disease is most common in puppies between 6 weeks and 6 months of age
 d. Rottweilers, Doberman pinschers, pit bull terriers, German shepherd dogs, and Labrador retrievers may be more susceptible to parvoviral infection
 B. Parvovirus attacks rapidly dividing cells (GI, hematopoietic, lymphoid tissues). The intestinal mucosal barrier can break down, leading to bacteremia
 C. Clinical signs
 1. Sudden onset of vomiting and diarrhea, with severe dehydration. Diarrhea can be profuse and foul-smelling and may contain blood
 2. DIC may occur
 3. Severe cases may result in death, especially in young puppies
 D. Diagnosis is usually based on clinical signs. Prior vaccination does not preclude the presence of parvovirus
 1. CBC: About 50% of dogs with parvovirus have severe leukopenia (lymphopenia, granulocytopenia). The PCV can be decreased because of intestinal blood loss or may be elevated from dehydration
 2. Serum chemistries typically show electrolyte abnormalities and evidence of dehydration
 3. Radiography shows gas and fluid distention of the GI tract
 4. Indirect fluorescent antibody test detects IgM antibodies giving evidence of recent infection
 5. Demonstration of excretion of virus or viral antigen in the feces provides definitive diagnosis of parvovirus. Rapid in-office tests are commercially available
 6. At necropsy, characteristic intestinal lesions of intestinal crypt cell necrosis are observed
 E. Treatment
 1. IV fluid therapy is the most important aspect of treatment
 a. Use a balanced crystalloid (e.g., Normosol-R, lactated Ringer's)
 b. Add potassium to avoid hypokalemia; monitor serum potassium daily
 c. Possibly add magnesium because in severe cases magnesium is often deficient
 d. Add dextrose to control hypoglycemia; monitor serum glucose concentrations
 e. Use hetastarch if balanced crystalloid solutions are not maintaining stability
 2. Broad-spectrum antibiotics (parenterally) help to control bacterial complications. Use cefazolin or ampicillin alone for mild cases or in combination with aminoglycosides or fluoroquinolones in severe cases. Beware of nephrotoxicity with aminoglycoside use
 3. Diet
 a. Give nothing orally for the first 12 to 24 hours. Partial parenteral nutrition may be needed if vomiting is prolonged

b. When starting to refeed, give small feedings of a bland, highly digestible diet (commercial GI diet). Transition gradually back to normal feedings
4. For vomiting, treat with metoclopramide. Gastric acid secretion can be controlled with ranitidine or famotidine
a. Chlorpromazine can be used if metoclopramide is unsuccessful but only after dehydration has been corrected
b. Do not use anticholinergics
5. Antidiarrheals are not usually needed as long as fluid therapy is intensive; loperamide can be used if necessary
6. Blood transfusion can be considered if there is anemia, and plasma infusion may be used in cases of concurrent DIC
7. Treat for septic shock if necessary

F. Prognosis and complications
1. If survive the first few days, most recover
2. Mortality is highest in young puppies
3. Complications include bacterial infections, other viral infections, liver disease, DIC, CNS signs

G. Prevention
1. Minimize exposure
a. Keep an infected dog isolated for at least a week after recovery
b. Keep young puppies isolated from other dogs and potentially infected areas until completely vaccinated
2. Vaccination
a. Maternal antibodies interfere with protection by vaccination; thus there is a 2- to 4-week period during which puppies may be susceptible to infection but refractory to vaccination
b. Vaccinate puppies with MLV CPV-2 vaccines every 3 to 4 weeks until about 14 weeks of age. Booster 1 year later, then every 3 years thereafter
c. Used killed vaccine to vaccinate pregnant dogs or for puppies less than 5 weeks of age

II. Canine coronavirus
A. Causes
1. Transmission is fecal-oral
2. Coronavirus is shed in feces for months after infection

B. Clinical signs: Acute mild diarrhea is most common, and there may be mild anorexia, depression, or vomiting
C. Diagnosis is based on clinical signs. Coronavirus can be detected in feces using electron microscopy (EM), virus isolation, or PCR
D. Treat with supportive therapy. Antibiotics are not usually necessary. Diarrhea may persist for 3 to 4 weeks
E. Prevention: Vaccines are available, but their efficacy and duration of immunity are questionable

III. Canine rotavirus
A. Causes
1. Transmission is fecal-oral
2. Highly infectious and persists in the environment

B. Clinical signs
1. Acute enteritis is seen in young puppies. This is usually self-limiting
2. Infection is subclinical in adult dogs

C. Diagnosis: Can be detected in feces by EM, PCR, or virus isolation
D. Treat with supportive therapy
E. There is no vaccine. Ensure that neonates receive colostrums

IV. Feline panleukopenia virus (FPV)
A. Causes
1. Infects all felines and also raccoons, ferrets, and minks
2. Shed in body secretions for 6 weeks
3. Resistant to inactivation but is inactivated with dilute sodium hypochlorite. FPV can survive in the environment for over a year
4. Affects rapidly dividing cells, especially intestinal crypt epithelium, lymphoid tissue, hemopoietic tissue, and nervous system in the developing fetus

B. Clinical signs
1. Young kittens usually show a high fever, vomiting, diarrhea, dehydration, and anorexia
2. In susceptible adult cats, infection is usually subclinical
3. Infection can occur in utero near the end of gestation or within the first few weeks of life. Infection at this time usually results in cerebellar hypoplasia with ataxia and intention tremors

C. Diagnosis is based on clinical signs in an unvaccinated kitten
1. Leukopenia can be profound and lasts 2 to 4 days. If leukopenia lasts more than 5 days or nonregenerative anemia is also present, consider FeLV infection
2. Definitive diagnosis requires fecal PCR or virus isolation

D. Treat supportively (intensive fluid therapy, antibiotics, antiemetics, dietary restriction)
E. Prognosis is poor if hypothermia, shock, jaundice, or DIC develops
F. Prevention
1. Vaccination is highly effective
2. Use killed vaccine in kittens less than 4 weeks old or in pregnant cats
3. With MLV vaccine, vaccinate kittens twice, 3 weeks apart. Give a booster 1 year later, then revaccinate every 3 years

V. Feline coronavirus
A. Inapparent infection is very prevalent and may cause mild enteritis
B. In kittens 1 to 3 months of age, there is an acute mild enteritis with diarrhea. Signs are typically self-limiting after 2 to 4 days
C. Serology can measure a coronaviral titer but cannot distinguish between active or previous infection
D. Treatment is supportive and often not necessary
E. An intranasal vaccine is available but is not effective

VI. Feline rotavirus
 A. Has been isolated from normal cats and from cats with diarrhea. Subclinical infection is frequent
 B. Clinical signs include a mild diarrhea in neonates for a few days
 C. Diagnosis: Detected in feces by EM, PCR, or ELISA
 D. Treat with supportive measures (fluid therapy, diet restriction)
VII. Feline astrovirus
 A. Transmission: Fecal-oral route
 B. Clinical signs include a mild diarrhea for 4 to 14 days
 C. Diagnosis: Detected in feces by EM or PCR
 D. Treat with supportive measures (fluids, diet restriction)

RABIES

I. Rabies is caused by a rhabdovirus that attacks the nervous system and is shed in saliva. Reservoir animals are skunks, raccoons, bats, foxes, and coyotes. Some can shed rabies for a long time with no evidence of clinical signs. Rabies is inactivated by most disinfectants
II. Pathogenesis. Rabies enters through a bite wound usually and travels along peripheral nerves to the CNS. Signs usually occur within 2 to 8 weeks. Virus is shed in the saliva for about 10 days before clinical signs appear, and shedding continues until death. Once clinical signs start, death occurs within 3 to 10 days
III. Clinical signs
 A. The first phase is prodromal and lasts for a few days. There may be subtle signs of erratic behavior
 B. The furious phase lasts 2 to 4 days, and signs of erratic behavior (such as aggression, irritability, pica, roaming) are evident. There may be ataxia, seizures, and paralysis
 C. The paralytic phase lasts 2 to 4 days, and there is ascending paralysis of the limbs and laryngeal and pharyngeal paralysis. This phase is followed by death
 D. Atypical rabies has occurred in dogs, cats, bats, and skunks in which they develop subclinical or chronic infections
IV. Diagnosis is accomplished postmortem. Chill the animal's head, but do not freeze
 A. Direct fluorescent antibody test is the test of choice. Brain or salivary glands can be tested
 B. Negri bodies (intracytoplasmic neuronal inclusions) can be seen in most rabid dogs (but not cats)
V. Treatment is not recommended, as rabies is fatal and poses a public health hazard. Any suspected case should be quarantined or euthanized
VI. Prevention in dogs and cats
 A. Vaccination is protective. Only inactivated and recombinant vaccines are available in the United States. Do not use rabies titers in animals, as they may not correlate with protection. Do not vaccinate wild animals or hybrids against rabies, as there are no vaccines licensed for these animals
 B. Postexposure management (animal bitten by known rabid animal)
 1. Report human and animal exposure to public health authorities
 2. If the exposed animal has been previously vaccinated, revaccinate immediately and have the owner observe for 45 days for any illness suggestive of rabies
 3. If the exposed animal is unvaccinated, euthanasia is recommended so that tissues may be examined. If euthanasia is not allowed, isolation is required for 6 months. If signs suggestive of rabies occur, euthanasia and testing are required
VII. Prevention in humans is critical as clinical cases are fatal
 A. Preexposure prevention for humans at high risk include immunization with human diploid cell vaccine
 B. Animal bites to humans
 1. If a healthy dog or cat bites a human (if there is possibility of that animal having contact with a rabid animal), the animal is confined, isolated, and observed by the owner for 10 days. Any signs of illness must be reported
 2. If a wild animal or dog or cat with unknown vaccination status bites a human, euthanasia with examination of tissues is recommended
 3. Human wounds should be cleansed vigorously; ethanol or benzalkonium chloride are good disinfectants
 a. Nonimmunized humans are given five doses of vaccine, and rabies immunoglobulin
 b. Immunized humans are given two doses of vaccine

PSEUDORABIES

I. Causes
 A. Herpesvirus that infects pigs (Aujeszky disease)
 B. Results from ingestion of contaminated raw pork
II. Clinical signs
 A. Fatal within 3 to 5 days after exposure
 B. Signs are similar to rabies or other encephalitis. Signs include intense pruritus (especially of the head and neck), depression, inactivity, anxiety, restlessness, fever, diarrhea, vomiting, hypersalivation, ataxia, seizures. Death within 48 hours of onset of clinical signs
III. Diagnosis
 A. Serologic tests used in pigs are not useful in dogs and cats
 B. Diagnosis is made postmortem, based on testing of unfixed brain tissue for virus
IV. Treatment. There is no known effective treatment
V. Prevention
 A. Prevent direct contact with pigs
 B. Never feed raw pork

MISCELLANEOUS VIRAL DISEASES

I. Infectious canine hepatitis (ICH)
 A. Caused by canine adenovirus type 1 (CAV-1). ICH is rare because of vaccination. Foxes, coyotes,

wolves, and bears are susceptible to ICH. Infection is via oronasal exposure. CAV-1 is very resistant to disinfection
 B. Clinical signs: There is usually a week-long course with fever, vomiting, diarrhea, abdominal pain, pharyngitis, lymphadenopathy, pneumonitis, and hemorrhage. CNS signs may occur. Ocular disease such as corneal edema or anterior uveitis may be present. Persistent chronic hepatitis may develop
 C. Diagnosis is based on clinical signs in unvaccinated dogs. ICH can be confirmed by serology, virus isolation, or histopathology (intranuclear viral inclusions)
 D. Treatment is supportive
 E. CAV-2 vaccination is very effective for prevention. CAV-1 vaccines are not recommended as they can cause an anterior uveitis, mild nephritis, and urine shedding of virus
II. Canine acidophil cell hepatitis
 A. Etiology. Transmissible; distinct from CAV-1 and CAV-2
 B. Clinical signs include acute hepatitis, chronic hepatitis, cirrhosis, and hepatocellular carcinoma. Signs reflect liver involvement
 C. Diagnosis
 1. Tests reflect liver disease, with alanine aminotransferase and alanine phosphatase elevations most consistent
 2. Diagnosis depends on liver biopsy
 D. Treatment and prevention: Provide supportive treatment for liver failure
III. Canine herpesvirus (CHV)
 A. Once infected, dogs remain carriers for life. CHV is readily inactivated in the environment. Transmission occurs in utero, during birth (contact with vaginal secretions), or by oronasal contact with secretions from an infected mother
 B. Clinical signs
 1. Fetal infection results in fetal resorption, late-gestation abortion, or stillbirth
 2. Neonatal systemic infection occurs from birth to about 3 weeks of age and leads to virus distribution to all tissues. Necrosis and hemorrhage of many organs occur. Clinical signs include refusal to nurse, continuous crying, low body temperature, petechial hemorrhages, with death within 24 to 72 hours
 3. Adults and older puppies are resistant to infections because of their higher body temperatures. Infection usually causes mild signs in the respiratory and genital tracts
 C. Diagnosis in newborn puppies is via clinical signs. Virus can be isolated from the oropharynx or genital lesions in adults
 D. Treatment is not effective. Puppies that do recover have neurologic dysfunction
 E. Isolate infected bitches and litters, disinfect the premises, and maintain warm ambient temperatures for newborn puppies
IV. Canine viral papillomatosis
 A. Caused by canine papillomavirus and occurs most commonly in young dogs. Transmission is by direct contact, and incubation is 1 to 2 months
 B. Oral papillomatosis is most common, with multiple nodules on the lips, oral mucosa, tongue, palate. These increase in size and number for about 4 to 6 weeks, then regress. Ocular or cutaneous papillomatosis are uncommon
 C. History and physical examination are diagnostic. PCR can confirm papillomavirus
 D. Treatment is not necessary for the oral form. Ocular nodules and some oral nodules should be removed. If nodules do not regress, vincristine can be used weekly
V. Feline poxvirus
 A. Caused by cowpox virus (orthopoxvirus); has been seen only in Europe and Asia in cats. Infection is from exposure to rodents
 B. After the primary lesion (usually a bite wound), viremia occurs, with mild systemic signs. Pox lesions develop that are small (1 mm) and numerous (10 or more) and are covered with scabs
 C. Diagnosis is based on history and clinical signs and can be confirmed with fluorescent antibody staining
 D. There is no specific treatment as skin lesions usually regress. Cowpox virus is potentially transmissible to humans
VI. Other viruses
 A. West Nile virus is a flavivirus in bird populations. It is transmitted by mosquitoes to birds, humans, horses, dogs, and cats. Meningoencephalitis occurs in birds, humans, and horses, but most dogs and cats have few clinical signs
 B. *Bornavirus* can cause fatal neurologic disease in dogs and cats, mostly in Europe and Japan. Human infection can occur, and transmission is presumed to be through a vector
 C. Other vector-borne viruses that can infect dogs and cats include equine togaviruses (equine encephalitis), flaviviruses, bunyaviruses (Rift Valley fever), and orbiviruses (African horse sickness)
 D. Avian influenza H5N1 can cause fatal pneumonia in cats
 E. *Hantavirus* is endemic in rodents and has been found in cats in North America, Europe, and Asia. In cats the infection is subclinical, but in humans *Hantavirus* is life-threatening, causing hemorrhagic fever, renal or pulmonary syndromes
 G. Feline foamy virus (spumavirus) was formerly called feline syncytium-forming virus. Infection is very common but does not cause clinical signs
 H. Feline spongiform encephalopathy has been observed in cats in the United Kingdom and is considered to be caused by the same prion that causes bovine spongiform encephalopathy (mad cow disease). Cats are infected via ingestion of infected meat. Cats develop neurologic signs after a long incubation period, and there is a slow progression to death. There is no treatment

RICKETTSIOSIS, EHRLICHIOSIS, ANAPLASMOSIS, NEORICKETTSIOSIS

I. Rocky Mountain spotted fever (*Rickettsia rickettsiae*)
 A. Caused by *R. rickettsiae* and in the United States is most prevalent in the Southeast, Midwest, and

Great Plains regions. It is transmitted by the American dog tick (*Dermacentor variabilis*) and the wood tick (*Dermacentor andersoni*). Rodents are the reservoir. Most infections occur in April through October (tick season)

B. Once bitten by a tick, the organism invades vascular endothelial cells, causing necrotizing vasculitis, edema, and damage of multiple organs. The incubation period is a few days to a few weeks, and clinical illness lasts 1 to 2 weeks with a high mortality rate

C. Clinical signs are usually acute and may include general signs of fever, anorexia, lethargy, joint pain, ocular signs, neurologic signs, vasculitis, petechial to ecchymotic hemorrhages, pneumonitis, and myocarditis

D. Thrombocytopenia is common, as is leukocytosis with a left shift, anemia, and toxic granulation of neutrophils

E. Diagnosis can be confirmed by serum antibody titers and PCR. The IFA test is diagnostic if there is a single high titer, or a four-fold increase in paired serum samples. There can be crossreactivity with other *Rickettsia* spp.

G. Doxycycline is the drug of choice for treatment. The prognosis is good if treatment is initiated early in the course of the disease

H. Minimize exposure to ticks. Rocky Mountain spotted fever is an important tickborne disease in humans, but dogs are a minimal zoonotic risk

II. Canine ehrlichiosis

A. Caused by a variety of species of *Ehrlichia*, including *E. canis, E. ewingii*, and *E. chaffeensis. Ehrlichia* is a gram-negative cocci that infects leukocytes

B. *E. canis* is transmitted via the brown dog tick (*Rhipicephalus sanguineous*) most frequently in the Southeast. *E. ewingii* is transmitted by the lone-star tick (*Amblyomma americanum*) and possibly other ticks most frequently in the Southern and Central United States. *E. chaffeensis* occurs in the South and is transmitted by the lone-star tick

C. *E. canis* and *E. chaffeensis* infect monocytes and phagocytes in lymph nodes, spleen, liver, and bone marrow. *E. ewingii* infects granulocytes. *E. canis* typically causes a long subclinical phase that can last for years before developing clinical signs of chronic infection

D. Acute signs of infection occur a few weeks after a tick bite, and signs last 2 to 4 weeks. Clinical signs of acute infection include fever, anorexia, lethargy, oculonasal discharge, lymphadenopathy, splenomegaly, hepatomegaly, and thrombocytopenia. Neurologic signs are infrequent. *E. ewingii* commonly causes polyarthritis. Antibody titers may be negative during the acute phase

E. After the acute phase, a long subclinical phase follows and can last from months to years. A variety of vague clinical signs occur in the chronic phase, including weight loss, fever, spontaneous bleeding, anemia, lymphadenopathy, splenomegaly, hepatomegaly, uveitis, polyarthritis, and limb edema. Clinical signs may be more severe in German shepherd dogs and Doberman pinschers. Nonregenerative anemia, thrombocytopenia, leukopenia, lymphocytosis, or plasmacytosis may be present. Some cases show a polyclonal gammopathy, or protein-losing nephropathy. Many signs may resemble multiple myeloma

F. Diagnosis

1. Serology using IFA is reliable; however, titers may not be detected until 2 to 4 weeks after infection. An antibody titer persists for about 9 to 12 months and does not protect against reinfection. Serology using the ELISA test kit only detects infection by *E. canis*.
2. PCR testing can identify the *Ehrlichia* species present
3. Intracellular *Ehrlichia* can be identified in blood leukocytes, and morulae can be seen in bone marrow cells or aspirates of lymph nodes. *E. canis* and *E. chaffeensis* are found in monocytes, and *E. ewingii* is found in neutrophils

G. Doxycycline is the treatment of choice. Clinical signs should improve within 48 hours, and platelets should start to increase within 2 to 7 days. The prognosis is good unless there is severe hypoplasia of the bone marrow

H. Ehrlichiosis is prevented by minimizing exposure to ticks. Ticks can transmit *Ehrlichia* occasionally to humans

III. Anaplasmosis

A. Caused by *Anaplasma phagocytophilum* that is transmitted by *Ixodes* ticks. The mouse is a reservoir. Most cases occur in the Northeast, upper Midwest, and Pacific Coast of California. Ticks can infect humans, dogs, cats, horses, small ruminants, and other wildlife

B. Clinical signs are usually seen in acutely infected animals. Signs are nonspecific and include fever, lethargy, arthralgia, and polyarthritis. Morulae may be observed in neutrophils and are identical in appearance to *E. ewingii*

C. Serum antibody titer or PCR can identify *A. phagocytophilum*

D. Doxycycline is the treatment of choice

E. Anaplasmosis is prevented by minimizing tick exposure

IV. Canine cyclic thrombocytopenia

A. Caused by *Anaplasma platys,* which replicates in platelets. It is thought to be spread via ticks and is most common in the Southeast and Gulf Coast states

B. Few clinical signs are observed. Moderate to severe thrombocytopenia develops in 14-day intervals

C. Diagnosis is by serology or PCR. *A. platys* morulae are sometimes seen as inclusions within platelets

D. Doxycycline is the treatment of choice

E. Minimize exposure to prevent

V. Neorickettsiosis (Potomac horse fever)

A. Caused by *Neorickettsia risticii* and can infect dogs and cats

B. The vector is a fluke that uses snails as an intermediate host. Infection is from ingestion of the

trematode stage in water or ingestion of infected snails
C. Clinical signs include lethargy, vomiting, petechial hemorrhages and bleeding, polyarthritis, edema, and posterior paralysis. Anemia, thrombocytopenia, and coagulopathy may be present
D. Diagnosis is by demonstration of a positive antibody titer against *N. risticii*
E. Doxycycline is the recommended treatment
F. Minimize exposure to standing water and snails to prevent transmission

VI. Salmon poisoning disease
A. Caused by *Neorickettsia helminthoeca* and found only in dogs in the Pacific Northwest. Cats are not susceptible
B. The vector is a fluke (*Nanophyetus salmincola*) infected with *N. helminthoeca*. Dogs are infected by ingesting raw salmon (or other fish) containing the infected fluke. An intermediate host snail that only lives in the Pacific Northwest is required for the life cycle
C. After ingestion, the flukes mature within the dog's intestine and infect the intestinal epithelium and mononuclear cells. They then disseminate to lymph nodes, spleen, liver, CNS, and lungs. This incubation period is from 5 to 21 days
D. Clinical signs include high fever, anorexia, hemorrhagic diarrhea, vomiting, weight loss, and lymphadenopathy. The acute onset can resemble canine parvovirus infection
E. Fluke ova are usually seen on direct fecal smears. Lymph node aspirates often show reactive lymphocytes with intracytoplasmic rickettsial bodies in macrophages
F. Doxycycline and tetracycline are the antibiotics of choice. Praziquantel eliminates flukes
G. Do not allow dogs to eat raw fish

VII. Feline *Ehrlichia*-like diseases
A. Cats can be infected with *E. canis*, *N. risticii*, and A. *phagocytophilum*. Tick vectors are likely for *Ehrlichia* and *Anaplasma*
B. Clinical signs include fever, lethargy, anorexia, GI signs, weight loss, polyarthritis. There may be a nonregenerative anemia, thrombocytopenia, or pancytopenia
C. Diagnosis has been confirmed by direct visualization of organisms in blood, serology, and PCR
D. Doxycycline, tetracycline, or imidocarb have been used for treatment
E. Minimize tick exposure to prevent

BORRELIOSIS (LYME DISEASE)

I. Causes
A. Borreliosis is caused by the spirochete *Borrelia burgdorferi* and is transmitted primarily by the deer tick (*Ixodes* spp.). Ticks must attach to skin for at least 48 hours to transmit *Borrelia.* Once in the skin, *Borrelia* spreads through connective tissue
B. Deer are not usually infected. Mice and other rodents are the reservoir hosts. Migratory birds may carry deer ticks long distances
C. Most cases occur in the Northeast states and also in Wisconsin and Minnesota, where as many as 80% of ticks may carry *Borrelia*
D. Clinical signs of disease are present in only 5% of infected dogs; subclinical infection is common

II. Clinical signs develop 2 to 5 months after exposure
A. Polyarthropathy causing shifting-leg lameness is the most common sign
1. Swelling and joint pain may be observed
2. Chronic arthritis may develop
3. Synovial fluid examination shows suppurative inflammation
B. Protein-losing glomerulopathy and renal failure have been associated with borreliosis, especially in Labrador retrievers and golden retrievers
C. Borreliosis is not well documented in cats, but many cats are seropositive for *Borrelia*

III. Diagnosis
A. Serologic tests for *Borrelia* antibodies
1. ELISA and IFA antibody titers
a. These tests do not differentiate between natural infection and vaccination titer
b. A titer increases within 4 to 6 weeks after exposure
c. Positive titers can persist for years. IgG and IgM titers are not useful
d. A negative titer rules out borreliosis, as false-negative titers are rare
2. C6 Antibody test is highly specific for *B. burgdorferi*
a. This test uses a C6 antigen that can detect C6 antibodies against an outer surface protein of *Borrelia* spp.
b. This test distinguishes between natural infection and vaccination, as only naturally infected dogs have C6 antibodies. This test also does not crossreact with antibodies against other spirochetes (*Leptospira*)
c. Early infections can be detected with the C6 antibody test, before the development of clinical signs
3. Western blot assay gives similar information as the C6 antibody test but is more cumbersome and expensive
B. PCR and culture can be used to identify organisms. It is best to use a skin biopsy from around the tick bite site. *Borrelia* can be difficult to culture

IV. Treatment
A. Doxycycline orally is the treatment of choice for dogs exhibiting clinical signs of borreliosis. The response is usually rapid. Use nonsteroidal antiinflammatory drugs to treat joint pain
B. Dogs that are seropositive but asymptomatic do not require treatment but should be monitored for lameness

V. Prevention
A. Vaccinate dogs at high risk (hunting dogs, outdoor dogs) in tick-infested areas
B. Avoid tick bites with topical fipronil, permethrin, or amitraz

VI. Public health
A. Most cases occur in the Northeast states and in Wisconsin and Minnesota

B. Reduce tick exposure to prevent human infection

SYSTEMIC BACTERIAL INFECTIOUS DISEASE

I. Leptospirosis
 A. *Leptospira* are spirochetes that colonize in the proximal renal tubules. In the United States, leptospirosis is usually caused by serovars *L. icterohaemorrhagiae, L. canicola, L. pomona, L. bratislava, L. grippotyphosa*, and *L. autumnalis*
 1. Wild animals such as rodents, raccoons, skunks, and squirrels are sources of infection
 2. Infection is via skin penetration with environmental organisms, especially in contaminated water. Infection can also come from contaminated food, bedding, or soil
 3. The prevalence of leptospirosis is increasing and is most common in periurban areas; however, all dogs are at risk. Late summer and early fall or after wet periods are the most common times of infection
 4. Bacteremia occurs about 4 to 12 days after infection, and the most common organ targets are the kidney and liver
 B. Clinical signs are acute in nature and mostly due to acute renal failure or acute hepatic failure in conjunction with DIC
 C. Diagnosis
 1. Azotemia and increased serum concentrations of liver enzymes are common. Thrombocytopenia can be severe
 2. On ultrasound, kidneys show increased echogenicity in 75% of cases and may have demarcation of the corticomedullary border (medullary rim sign)
 3. Serology
 a. Microscopic agglutination titer can indicate current or past infection, or leptospiral vaccination. A high single titer (i.e., 1:800) or a four-fold increase in paired serum samples suggests current infection. Different serovars can be tested
 b. Combined immunoglobulin titers can distinguish natural infection from prior infection or vaccination but cannot distinguish between serovars
 4. *Leptospira* organisms can be identified by darkfield microscopy of fresh urine. Culture is difficult and is rarely used for diagnosis
 D. Treatment can be effective in 75% to 90% of cases, although chronic renal failure is a common outcome. In the initial phase, supportive care is given for acute renal failure, and penicillin or amoxicillin is used. After the amoxicillin therapy, doxycycline is used to eliminate the renal carrier state
 E. Vaccines can reduce the incidence of leptospirosis. A multivalent vaccine containing the serovars *L. pomona*, *L. grippotyphosa*, *L. canicola,* and *L. icterohaemorrhagiae* give the broadest protection. Anaphylactic reactions can occur, especially in small breeds and puppies under 9 weeks of age
 F. Humans are infected primarily through contaminated water. Rodent control is important in prevention of leptospirosis. Urine should be avoided from infected dogs. Use an iodophor as a disinfectant to clean urine

II. Brucellosis
 A. Caused by *Brucella canis,* which is a gram-negative coccobacillus
 B. Transmission is via semen, vaginal discharge, urine, or aborted fetal tissue
 C. *Brucella* organisms can live for long periods within mononuclear phagocytes. Bacteremia usually occurs about 1 to 4 weeks after infection and can last more than 5 years
 D. Most dogs have no clinical signs, but there may be lymphadenopathy, splenomegaly, and reproductive failure. Males typically have testicular atrophy, epididymitis, and sterility. Infected females fail to conceive, or they abort dead fetuses late in gestation
 E. Diagnosis
 1. A rapid slide agglutination test (RSAT) is used for screening, but false-positives are common. Any animal that shows a positive reaction on the RSAT should be confirmed by a more specific test. False-negatives are rare
 2. Agar gel immunodiffusion (AGID) is the best test for confirmation of a positive RSAT result
 3. The tube agglutination test can be used to confirm a positive RSAT result; however, false-positive results do occur
 4. A positive blood culture is the most definitive proof of brucellosis
 F. Treatment is difficult because *Brucella* is refractory to antibiotics as a result of being intracellular. Relapses occur, so several courses of antibiotics may be needed. Minocycline and dihydrostreptomycin are used in combination. Ovariohysterectomy or castration is recommended
 G. All breeding animals should be screened for brucellosis before each breeding for females and at least twice yearly in stud dogs. Brucellosis-positive dogs should be removed from a breeding program
 H. Canine brucellosis has a low public health risk, but human infection from infected dogs has been documented

III. Bartonellosis
 A. Feline bartonellosis (cat scratch disease)
 1. Cause
 a. Cats are the main reservoir for *Bartonella henselae* but may also be a reservoir for *B. clarridgeiae*, *B. koehlerae*, and *B. bovis*
 b. Transmission is through fleas but can occur through blood transfusions. Prevalence is high in flea-infested areas. Cats younger than 1 year are most commonly infected
 2. Clinical signs are rare in cats, and most with bacteremia are clinically healthy. Occasionally fever, lymphadenopathy, uveitis, gingivitis, endocarditis occur
 3. Diagnostic testing should be performed only in those exhibiting clinical signs

4. Serology indicates exposure. Blood culture or PCR can prove active infection
5. Antibiotics such as macrolides (azithromycin) or fluoroquinolones (enrofloxacin) are indicated only if clinical signs are present
6. Flea control is the best method of prevention
7. In humans, bartonellosis is characterized by a small granuloma at the site of a cat scratch after 7 to 12 days. A few weeks later there is regional lymphadenopathy, which usually resolves within 2 to 3 months. Signs can be more severe in immunocompromised people. Immunocompromised owners should avoid cats younger than 1 year and avoid being scratched; pets need to be kept free of fleas

B. Canine bartonellosis
1. Causes
 a. Infection is most often due to *Bartonella henselae* or *B. vinsonii* (ssp. *berkhoffii*). *B. vinsonii* (*berkhoffii*) is more commonly associated with clinical signs
 b. *B. vinsonii (berkhoffii)* is transmitted by ticks (usually *Rhipicephalus sanguineous*), and coyotes are a major reservoir in California. *B. vinsonii (berkhoffii)* has been found worldwide
 c. *B. henselae* and other *Bartonella* species are transmitted by fleas. There is a high seroprevalence in the southeastern United States, where there are many fleas
2. Clinical signs include a transient fever with a persistent bacteremia and immunosuppression. A number of conditions are showing association with bartonellosis, especially aortic valve endocarditis, unexplained granulomatous disease, unexplained epistaxis, or immune-mediated disease
3. About half the dogs with clinical bartonellosis have thrombocytopenia, and about one third have eosinophilia. ANA tests can be positive with bartonellosis
4. Diagnosis is based on serum antibody titers or on PCR. Culture of blood is rarely successful
5. Severe disease is treated with aminoglycosides and a penicillin derivative. Chronic disease is treated with azithromycin or a combination of fluoroquinone and amoxicillin
6. Reduce the exposure to ticks to prevent bartenellosis
7. Do not use dogs with *Bartonella* as blood donors

IV. Mycobacteriosis
A. Causes
1. Mycobacteria are acid-fast, gram-positive bacteria that cause persistent infection that leads to granulomatous inflammation
2. *M. tuberculosis* is transmitted from humans to pets via inhalation; pulmonary infection is common
3. Infection with *M. bovis* is from unpasteurized milk or raw meat. More common in cats; the intestinal tract is usually involved
4. *M. avium* infection is from contaminated soil or water. Basset hounds and Siamese cats are genetically predisposed

B. Clinical signs are related to the site of the granulomatous inflammation and are usually chronic. Pulmonary infection is common in dogs with *M. tuberculosis*. Cats more commonly have *M. bovis*, and the GI tract is affected. *M. avium* can cause disseminated mycobacteriosis
C. Diagnosis is based on finding club-shaped acid-fast bacteria in lesions. Culturing *Mycobacteria* may take 6 weeks
D. Infections with *M. avium* are treated with a combination of rifampin, enrofloxacin, and azithromycin. Euthanasia is recommended in those with systemic disease or infected with *M. tuberculosis* or *M. bovis* as a result of zoonotic potential

V. Tularemia
A. Caused by *Francisella tularensis*, a gram-negative coccobacillus. In the United States, most cases occur in Arkansas, Missouri, Oklahoma, and South Dakota. Transmission can be via a number of routes, including tick and deerfly bites, bites from infected animals, inhalation, or ingestion. Ticks, rodents, and rabbits are the primary reservoir, but cats, dogs, livestock, and humans are also susceptible
B. Clinical signs are more common in cats and include anorexia, depression, fever, oral ulcers, pneumonia, and hepatic necrosis
C. Diagnosis is by serologic testing. Bone marrow, lymph nodes, or blood can also be cultured
D. Affected animals can transmit infection to people. Gentamicin, enrofloxacin, or doxycycline is used

VI. Feline plague
A. Caused by *Yersinia pestis,* a gram-negative coccobacillus. The primary reservoirs are rodents, and fleas transmit the disease to pets and humans. In the United States, it is most common in the western states. Cats are more commonly affected than are dogs
B. Clinical signs rapidly progress, with an incubation period of 1 to 4 days
1. Bubonic plague is most common in cats, most often affecting submandibular lymph nodes
2. Pneumonic plague causes pneumonia and abscessation in the lung. Animals with pneumonic plague are a serious public health risk
3. In septicemic plague there is widespread dissemination to organs

C. Diagnosis is based on finding gram-negative coccobacilli in lymph node exudates. Serology, antigen detection, or culture can be used to confirm
D. Affected animals can transmit infection to people. Parenteral gentamicin is the drug of choice. Doxycycline can also be used

SYSTEMIC MYCOSES

I. Histoplasmosis
A. Causes
1. Caused by *Histoplasma capsulatum,* which is found in the soil
2. In the United States, it is most prevalent in the Mississippi, Ohio, and Missouri River regions

3. Route of infection is by inhalation of spores; intestinal infection from ingestion can also occur

B. Pathogenesis
1. Incubation period of 12 to 16 days
2. Invades the lungs and then spreads to the mononuclear phagocyte system (i.e., spleen, liver)
3. More prevalent in young animals (i.e., younger than 4 years)
4. More common in sporting and hound breeds

C. Clinical signs
1. Subclinical infection of the respiratory tract is the most common outcome. May see multiple, calcified interstitial foci in the lungs
2. Acute pulmonary infection
 a. Causes severe pneumonia, and death may occur
 b. Radiographically, diffuse or nodular interstitial pulmonary infiltrates are observed
3. Chronic pulmonary infection
 a. Causes chronic pneumonia and is more common than an acute pulmonary infection
 b. Clinical signs include chronic cough, exercise intolerance, mild dyspnea
 c. Enlargement of the tracheobronchial lymph nodes and nodular interstitial infiltrates are seen on radiographs
4. Intestinal infection
 a. Occurs more commonly in dogs
 b. Can affect small or large intestine, with granulomatous thickening of the bowel wall
 c. Signs include diarrhea, progressive weight loss, anorexia, lethargy, fever, anemia, vomiting, and abdominal effusion
5. Disseminated infection
 a. Clinical signs include anorexia, depression, fever, weight loss, and signs dependent on the organs involved
 b. Organs involved can include bone marrow, lymph nodes, liver, spleen, peritoneum, eyes, CNS, skin, bone, or oral cavity

D. Diagnosis
1. Hematology
 a. Normocytic, normochromic nonregenerative anemia is common
 b. Subclinical thrombocytopenia is common
 c. May see neutrophilic leukocytosis or neutropenia. Pancytopenia is occasionally seen in cats
2. Serum chemistry evaluation may reveal hypercalcemia, hypoalbuminemia, or elevated liver enzymes if there is hepatic involvement
3. Imaging
 a. Radiographs show tracheobronchial lymphadenopathy, diffuse or nodular interstitial pulmonary infiltrates, or calcified pulmonary interstitial nodules (if inactive)
 b. Depending on organs involved, there may be splenomegaly, hepatomegaly, abdominal effusion, bone lesions, or thickening of the intestinal wall
4. Serology is unreliable, and it is better to confirm infection by identifying the organism
5. Cytology is the best method for diagnosis. Organisms are usually within the cytoplasm of macrophages and appear as round to oval structures, 2 to 4 μm in diameter, surrounded by a clear halo
6. Histopathology usually shows granulomatous inflammation, but organisms can be difficult to find
7. Culture: Grows on Sabouraud's dextrose agar at room temperature in 7 to 10 days

E. Treatment
1. Itraconazole is the treatment of choice. Treat for a minimum of 4 to 6 months
2. Itraconazole plus amphotericin B is used when severe infection is present. The combined therapy is followed by use of itraconazole alone for at least 2 to 4 months
3. Fluconazole is used for ocular and neurologic infections
4. Ketoconazole is not as effective as itraconazole but is less expensive

II. Blastomycosis

A. Cause
1. Cause is *Blastomyces dermatitidis* in the soil
2. Distribution is in the Great Lakes regions of the United States, especially around the Mississippi and St. Lawrence Rivers. The organisms live in sandy, acidic soil near water
3. Infection is via inhalation of spores. Focal skin infection can also occur by direct contact
4. Dogs are very susceptible to blastomycosis. Young large-breed, sporting, and hound breeds are most commonly affected because of increased exposure opportunities. Blastomycosis is rare in cats

B. Clinical signs
1. Pulmonary infection is present in 85% of cases and can include pyogranulomatous pneumonia, alveolar consolidation, solitary lung masses, and pleural effusion
2. Disseminated infection is common to lymph nodes, skin, eyes, and bone. Infection can also occur in the CNS, male genitalia, oral or nasal cavities, and abdomen

C. Diagnosis
1. Hematology and serum chemistries
 a. Neutrophilic leukocytosis, monocytosis, lymphopenia, and mild regenerative anemia are most common
 b. Hypercalcemia is noted in some cases
 c. Mild hypoalbuminemia may be noted
2. Imaging: Radiographs of the lungs show diffuse interstitial infiltrate or nodular patterns in most cases
3. Serology: The AGID test is the most reliable
4. Cytology is the most useful tool for diagnosis
 a. Thick-walled extracellular yeast bodies (5 to 20 μm) with broad-based budding are observed
 b. Organisms can also be identified in biopsy specimens
5. Culture: Growth occurs after 1 to 4 weeks

D. Treatment
1. Itraconazole is the treatment of choice. Treat for at least 2 to 3 months
2. Itraconazole plus amphotericin B is used in severe infections
3. Amphotericin B alone can be used, but has a high risk of nephrotoxicity
4. Fluconazole is less effective than itraconazole but is used for infections of the eyes, CNS, or prostate
5. Ketoconazole is less effective but is less expensive
6. Treatment is successful in about 75% of cases. Blindness can result from ocular infection, and relapses can occur in about 20% of recovered cases

III. Coccidioidomycosis (Valley fever)
A. Causes
1. *Coccidioides immitis* in the soil
2. Found in dry, desert-like areas of the southwestern United States, Mexico, Central and South America. Fungi grow during rainy periods, then become airborne when the soil dries
3. Infection is by inhalation of spores, and the incubation period is up to 3 weeks

B. Clinical signs
1. Subclinical pulmonary infection is the most common form of natural infection
2. Pulmonary infection is characterized by chronic granulomatous pneumonia
3. Disseminated infection can involve bones and joints, skin, lymph nodes, spleen, liver, kidneys, heart, CNS, or eyes. Fever, anorexia, lethargy and weight loss are common. Skin lesions are more common in the cat, and bone lesions are more common in the dog

C. Diagnosis
1. Hematology and serum chemistries may show leukocytosis, monocytosis, and mild nonregenerative anemia. There may be hyperglobulinemia and hypoalbuminemia, especially if chronic
2. Imaging
a. There is usually a diffuse or nodular pulmonary interstitial pattern seen on radiographs
b. Pericardial effusion may be observed
c. Dissemination to bone is less common
3. Serology
a. The tube precipitin test detects the early IgM response
b. The complement fixation test detects the later IgG response
c. Newer immunodiffusion and ELISA tests for detecting *Coccidioides*-specific IgM and IgG are more reliable
4. Cytology or biopsy: *Coccidioides* spherules are large (20 to 200 μm) but may be infrequent and difficult to find
5. Can be cultured on routine fungal media

D. Treatment
1. Itraconazole or ketoconazole for at least 8 months
2. Amphotericin B is also effective

IV. Cryptococcosis
A. Causes
1. *Cryptococcus neoformans*
2. High concentrations can be found where pigeons roost
3. Route of infection is by inhalation

B. Clinical signs
1. Nasal infection
a. Chronic upper respiratory signs are common with cryptococcosis, including sneezing, sniffling, or mucopurulent nasal discharge
b. Obstructing masses may occur in the nostrils
2. Disseminated infection
a. Organs involved may include skin, CNS, eyes, lungs, peripheral lymph nodes, bone marrow, kidneys, liver, spleen, heart, and skeletal muscle
b. The skin, eyes, and CNS are most commonly infected

C. Diagnosis
1. Hematology is usually normal
2. Imaging may show increased density in the nasal cavity and sinuses
3. Serology
a. The test used is a capsular antigen test, detecting the presence of the organism
b. False negatives may occur if the disease is localized
4. Cytology or biopsy is the best method for diagnosis. *Cryptococcus* is easy to identify because of its prominent unstained capsule, and budding (Figure 18-1)
5. Culture: *Cryptococcus* will grow, but can take up to 6 weeks

D. Treatment is carried out for 6 to 12 months
1. Fluconazole is the treatment of choice because of its good penetration of the eyes and nervous system
2. Itraconazole is effective in many cases. Ketoconazole is not as effective

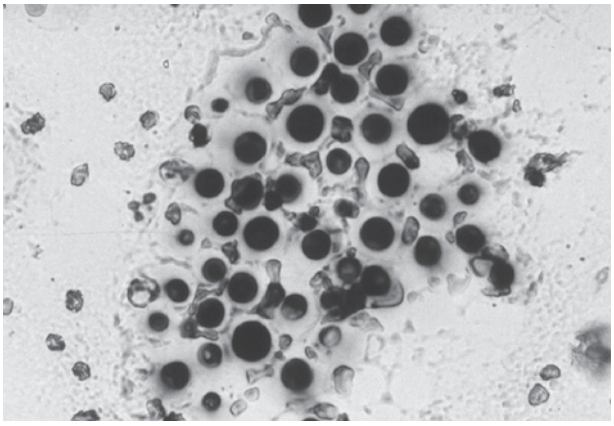


Figure 18-1 Cryptococcal organism noted on fine-needle aspirate cytology (from a dog with periocular swelling). Note the large capsules surrounding the organisms and the minimal inflammatory response. (From Ettinger SJ, Feldman EC: *Textbook of veterinary internal medicine,* 6th ed., St Louis, 2005, Saunders.)

3. Amphotericin B is effective, but nephrotoxicity is a problem
4. The prognosis is good for cats if there is no CNS involvement. Prognosis is guarded for dogs or in cats with CNS involvement

SYSTEMIC PROTOZOAL INFECTIONS

I. Toxoplasmosis
 A. Cause
 1. *Toxoplasma gondii*
 2. The cat is the definitive host, and the dog and other mammals serve as the intermediate host
 B. Routes of transmission
 1. Ingestion of tissue cysts from raw meat
 2. Ingestion of food, water, or soil that is contaminated with cat feces containing oocysts
 3. Transplacental
 C. Stages of infection
 1. Intestinal replication and oocyst shedding occur in cats only
 a. Also called the *sporozoite stage*
 b. Oocyst shedding lasts for 1 to 3 weeks
 c. There may be a transient diarrhea at this time
 2. Dissemination and intracellular replication
 a. Also called the *tachyzoite stage*
 b. Toxoplasma disseminates to tissues via blood
 c. Tachyzoites infect cells and then rupture, resulting in necrosis and inflammation
 d. Immunity develops, and the aggregates of the organism encyst
 3. Chronic tissue encystment
 a. Also called the bradyzoite stage
 b. Large tissue cysts form in muscle, brain, and organs
 c. These cysts can stay dormant for the life of the carrier
 d. Cysts may rupture if there is a loss of host immunity and infection is reactivated to an active stage
 D. Clinical signs
 1. Recognized more frequently in cats; clinical signs are similar in the dog
 2. Clinical signs are dependent on the organs affected
 3. Commonly affected organs include lungs, eyes, liver, pancreas, CNS, and skeletal muscle
 4. In the eye, toxoplasmosis causes uveitis, blindness, and chorioretinitis
 5. Pneumonia is common if the lungs are affected
 6. Neuromuscular signs can be caused by encephalomyelitis or myositis
 7. Hepatic and digestive tract signs occur
 8. Myocarditis
 9. Stillborn kittens or neonatal death
 E. Laboratory and radiographic findings are variable and dependent on organs involved
 F. Diagnosis
 1. Serum IgM titer elevates a few weeks after exposure and coincides with clinical signs; thus it is the best test for a diagnosis of an active infection
 2. Serum IgG titer elevates 2 to 4 weeks after exposure and may remain elevated for life; thus it does not distinguish from previous or active infection
 3. Titers can also be measured in cerebrospinal fluid and aqueous humor
 4. PCR of blood, cerebrospinal fluid, or aqueous humor may be positive in cats with or without clinical disease
 5. Intracellular inclusions are sometimes seen on impression smears or in biopsies
 6. Fecal oocysts are rarely identified since shedding occurs before clinical signs
 G. Treatment
 1. Clindamycin is the drug of choice
 2. Mortality is high in very young or immunosuppressed cats
 H. Prevention in cats. Do not let cats consume raw meat (especially birds and mice) or drink unpasteurized milk
 I. Public health considerations
 1. Preventive measures in humans
 a. Do not eat raw meat (especially pork)
 b. Change litter boxes daily, wear gloves when gardening, wash any fruits or vegetables before eating
 c. If pregnant or immunosuppressed, avoid contact with litter boxes and soil
 2. Direct contact with infected cats does not pose a high risk for infection
 3. Environmental control consists of decreasing the stray cat population and keeping cats away from livestock and livestock feeds

II. Neospirosis
 A. Cause
 1. *Neospora caninum*, a coccidia
 2. Dogs and wild canids are definitive hosts; other animals such as cattle or deer are intermediate hosts
 3. Infection occurs via ingestion of infected meat, or transplacentally
 4. Dogs shed oocysts in their feces, which can infect cattle and cause abortion
 B. Clinical signs
 1. Neuromuscular signs are most common, including paresis, ataxia, ascending paralysis, muscle atrophy, and contracture
 2. Other signs include myocarditis, pneumonia, dermatitis, chorioretinitis, and abdominal dissemination
 3. Females can pass *Neospora* in utero to puppies, often causing fetal or neonatal puppy death
 C. Laboratory and radiographic findings
 1. Because there is muscle involvement, increased levels of muscle enzymes (CK, AST) are observed
 2. Cerebrospinal fluid may show increased protein and leukocytes
 3. There may be alveolar or interstitial infiltrates
 D. Diagnosis is based on clinical signs and a positive titer for *Neospora*
 E. Treatment is similar to that for toxoplasmosis using clindamycin, trimethoprim-sulfadiazine, and

pyrimethamine. Treat all littermates of infected puppies

III. Hepatozoonosis
 A. Causes
 1. Tick-borne disease caused by *Hepatozoon americanum* or *Hepatozoon canis*
 2. *H. americanum* infection is typically in the Gulf Coast region and is transmitted by the Gulf Coast tick, *Amblyomma maculatum*
 3. *H. canis* is found in Southern Europe, Middle East, Africa, and Asia and is transmitted by the brown dog tick, *Rhipicephalus sanguineous*
 4. Infection occurs when a dog ingests an infected tick
 B. Pathogenesis
 1. After ingestion, *H. americanum* disseminates and forms numerous tissue cysts, especially in muscle tissue
 2. *H. canis* causes mild clinical signs and does not disseminate to muscle or bone
 C. Clinical signs begin within 4 weeks of ingesting an infected tick and may include fluctuating fever, muscle pain, stiffness, lameness, hyperesthesia, weight loss, weakness, muscle atrophy, mucopurulent ocular discharge, transient diarrhea, and protein-losing glomerulopathy
 D. Laboratory and radiographic findings
 1. An extreme neutrophilic leukocytosis is characteristic
 2. Increased ALP, hypoglycemia, hypoalbuminemia, and hyperglobulinemia are common
 3. Most infected with *H. americanum* have periosteal bony proliferations, especially on the pelvis, long bones, and vertebrae
 E. Diagnosis is made by identification of *H. americanum* organisms in skeletal muscle biopsies. *H. canis* can be found on blood smears. Serologic testing is also available
 F. Treatment does not eliminate *H. americanum* from tissues
 1. For *H. americanum*, combinations of clindamycin, trimethoprim-sulfadiazine, and pyrimethamine are used, followed with decoquinate for at least 2 years, and possibly lifelong
 2. Avoid corticosteroids
 3. For *H. canis*, imidocarb is highly effective

IV. Leishmaniasis
 A. Causes
 1. Flagellated protozoal parasites
 2. Rodents and dogs are reservoir hosts; the sand fly is a vector
 3. Endemic in the Mediterranean region
 4. *Leishmania infantum* is the most frequent cause of visceral leishmaniasis in dogs
 5. Occurs most frequently in foxhounds
 6. Infection can also occur from contaminated blood used for transfusions
 B. Clinical signs
 1. Dogs can be subclinically infected for months to years before developing clinical signs
 2. Clinical signs include fever, chronic weight loss, vomiting, diarrhea, lymphadenopathy, granulomatous dermatitis, elongated brittle toe nails, uveitis, coughing, sneezing, polyarthritis, glomerulonephritis, icterus
 C. Laboratory findings include thrombocytopenia, anemia, lymphopenia, leukocytosis with a left shift, hyperglobulinemia, hypoalbuminemia, proteinuria, azotemia, and presence of antinuclear antibodies
 D. Diagnosis is based on clinical signs, history of international travel, breed, and antibody titer
 1. Titers develop 2 to 4 weeks after infection and decline with treatment. *Trypanosoma* causes cross-reacting antibodies
 2. Organisms may be observed in aspirates of bone marrow, lymph nodes, and spleen or impression smears of skin or organs
 3. PCR can detect *Leishmania* DNA in aspirates of bone marrow, lymph nodes, or spleen
 E. Treatment is aimed at controlling the disease, but is not curative
 1. Relapses are common after treatment has stopped
 2. The following drugs have been used for treatment: Allopurinol, meglumine antimonite, sodium stibogluconate, and amphotericin B

Supplemental Reading

Birchard SJ, Sherding RG, eds. *Manual of small animal practice*, 2nd ed, St Louis, 2006, Saunders.

Greene CE, ed. *Infectious diseases of the dog and cat*, 3rd ed, St Louis, 2006, Saunders.

Ettinger SJ, Feldman, EC, eds. *Textbook of veterinary internal medicine,* 6th ed, St Louis, 2005, Saunders.

Hartmann K. Feline infectious peritonitis. *Vet Clin North Am Small Anim Pract* 35:39-79, 2005.

King LG, ed. *Textbook of respiratory disease, dogs and cats*. St Louis, 2004, Saunders.

Levy JK. CVT update: Feline immunodeficiency virus. In Bonagura JD, ed. *Kirk's current veterinary therapy XIII small animal practice,* Philadelphia, 2000, Saunders, p. 284.

Rojko JL, Hardy WD Jr. Feline leukemia virus and other retroviruses. In Sherding RG, ed. *The cat: Diseases and clinical management,* 2nd ed, Philadelphia, 1994, Saunders, p. 263.

Nervous System Disorders

19 CHAPTER

Patricia A. Schenck

DIAGNOSTIC APPROACH

I. Principles of neurologic examination
 A. Determine whether neurologic disease is present, and localize the lesion
 B. Perform examination in a consistent manner
 1. Start with a general examination and progress to a specific examination
 2. Do painful parts of the examination last

II. Procedures for the neurologic examination
 A. General observations
 1. Mental status is regulated by the brainstem and cerebrum
 a. Evaluate level of consciousness (alert, depressed, stuporous, comatose)
 b. Evaluate behavior (appropriate, demented). Dementia reflects a cerebral disorder
 2. Head posture is reflective of the vestibular system. A head tilt suggests a vestibular injury
 3. Coordination of head movement is regulated by the cerebellum
 4. Circling is usually toward the diseased side. Any brain lesion can cause circling
 B. Gait and stance
 1. A normal gait requires integration of the entire nervous system
 a. Ataxia is rarely caused by cerebral or peripheral nerve lesions
 b. Cerebellar lesions typically cause ataxia
 c. Cerebral lesions may produce mild weakness
 d. More pronounced weakness is caused by injury to the brainstem, spinal cord, or peripheral spinal nerves
 2. An abnormal stance may be caused by decreased proprioception, weakness, or pain
 C. Tests of postural reactions
 1. General findings
 a. Cerebral lesions: Postural deficit is on the opposite side of the body (contralateral)
 b. Brainstem lesions: Postural deficits are bilateral, but worse on the same side as the lesion (ipsilateral)
 c. Cerebellar, spinal cord, peripheral nerve lesions: Postural deficits are ipsilateral
 d. Vestibular lesions: Postural reactions are preserved, but the animal leans or falls toward the diseased side
 2. Proprioceptive positioning: Turn paw so animal bears weight on dorsal surface. The animal should quickly flip the paw over to the normal position
 3. Hemihopping: Hold limbs on one side off the ground and hop the animal sideways on the other two limbs. If conscious proprioception (CP) is intact and there is adequate strength in the limbs, a normal hopping response is quickly initiated
 4. Wheelbarrowing: Hold either front or hind legs off the ground and walk the animal forwards and backwards. A normal animal can walk easily
 D. Cranial nerve examination
 1. Menace response: Make a menacing gesture toward the animal; a normal animal should try to avoid the gesture. Tests both cranial nerves (CN) 2 and CN7.
 2. Pupillary light reflex: Illuminate the eye with a bright light; both pupils should constrict. Tests both CN2 and CN3. Lesions of CN2 cause loss of constriction in both pupils when the affected eye is examined. Lesions of CN3 cause loss of constriction in the affected eye, with constriction in the unaffected eye, regardless of which eye is illuminated
 3. Pupillary symmetry evaluates CN3 and the sympathetic nerve to the eye. If CN3 is abnormal, the large pupil is denervated, and the papillary light reflex (PLR) is absent. If the sympathetic nerve is damaged, the smaller pupil is abnormal, but the PLR is normal in both eyes
 4. Pupillary size reflects the integrity of CN3 and sympathetic nerve. Large pupils can be due to CN3 paralysis. Small pupils may be due to loss of sympathetic tone
 5. Ocular position is determined by CN3, CN4, CN6, and CN8
 a. Injury to CN6 causes medial strabismus
 b. Injury to CN3 or CN8 causes ventrolateral strabismus
 6. Ocular motility
 a. Voluntary eye movement requires cerebral, CN3, CN4, and CN6 activity. With a cerebral lesion, both eyes look toward the diseased hemisphere. With a CN lesion, only one eye is involved
 b. Nystagmus involves involuntary eye movements

(1) Vertical nystagmus suggests central vestibular disease
(2) Horizontal nystagmus suggests peripheral vestibular disease
(3) Rotatory nystagmus suggests either peripheral or central vestibular lesions
(4) Resting nystagmus suggests peripheral vestibular disease but can occur with central vestibular lesions
(5) Positional nystagmus occurs when the head is in an abnormal position and suggests central vestibular lesions

7. Facial symmetry assesses CN7; abnormalities suggest a cerebral lesion if contralateral, and brainstem or peripheral nerve lesions if ipsilateral
8. Palpebral reflex assesses CN5 and CN7. Touch the palpebral margins to produce a blink normally
9. Corneal reflex tests CN5 and CN7. Touching the cornea should produce a normal blink
10. Retractor oculi reflex tests CN5 and CN6. Touching the cornea should produce a retraction of the eye into the orbit normally
11. Facial sensory examination tests CN5. Stimulation of the nasal mucosa should result in an avoidance response
12. Gag reflex tests CN9, CN10, and brainstem. Lack of a swallowing reflex indicates either a brainstem injury or CN injury
13. Tongue atrophy indicates either a brainstem or CN12 lesion. Deviation of the tongue can be caused by cerebral injuries

E. Spinal reflex examination
1. Proprioceptive reflexes. A standard grading of the reflex is useful
a. Triceps reflex evaluates the radial nerve from C7 to T2. Normally there should be a slight extension of the elbow
b. Extensor carpi radialis reflex also evaluates C7 to T2. Normally the carpus extends
c. Biceps reflex evaluates the musculocutaneous nerve (from C6 to C7)
d. Patellar reflex tests femoral nerve and L4 to L6. An exaggerated response suggests an upper motor neuron (UMN) lesion
e. Cranial tibialis reflex tests the peroneal branch of the sciatic nerve from L6 to S2
2. Nociceptive spinal reflexes are initiated by a painful stimulus. Loss of the reflex suggests a lower motor neuron (LMN) lesion
a. Thoracic limb flexor reflex tests spinal cord segments C6 to T2
b. Pelvic limb flexor reflex tests segments L6 to S2
c. Perineal reflex tests S1 to S3
3. Special reflexes
a. Babinski reflex is in the hindlimbs. Stroking the plantar aspect of the metatarsus should cause slight flexion of the toes, or no response. A positive Babinski reflex signifies UMN disease, and the toes spread apart and elevate
b. Crossed extensor reflex. With UMN disease, the stimulated limb flexes and the contralateral limb extends

F. Nociceptive evaluation
1. Decreased pain perception can be the result of peripheral nerve, spinal cord, brainstem, or cerebral lesion
2. Increased sensitivity or exaggerated response to pain. A nonpainful stimulus is applied down the spine, looking for an area of acute response to the stimulus

III. Interpretation of the neurologic examination
A. Central nervous system (CNS) vs. peripheral nerve disease
1. If there are proprioceptive deficits, then lesion is most likely within the CNS
2. If there are UMN signs, there is usually a CNS lesion
3. If seizures or altered consciousness is present, a CNS lesion is usually the cause
4. If there are CN deficits and limb signs, the lesion is in the CNS
5. If there are CN deficits with no other signs, the lesion is most likely in the peripheral nervous portion of the CN
6. If there is diffuse weakness, diminished reflexes, without postural deficits, the lesion is usually in the peripheral nervous system

B. Location of lesion
1. If clinical signs are only in the limbs, the lesion is most likely below the foramen magnum
2. If there are CN deficits, seizures, altered consciousness, or abnormal head posture, the lesion is most likely above the foramen magnum

IV. Diagnostic testing: general
A. Hematology: Usually minimal changes
B. Biochemical tests: Alterations in blood glucose, calcium, potassium, and sodium can impact nervous system function. In addition, acid-base status, uremia, hyperlipidemia, hyperammonemia, and hyperviscosity can cause neurologic signs
C. Urinalysis: Metabolic diseases that impact the nervous system—such as diabetes, renal disease, and liver disease—can produce changes in the urine
D. Ophthalmologic examination is warranted if there is inflammatory disease
E. Blood pressure measurement is warranted as hypertension can predispose to CNS vascular disease
F. Thoracic radiographs and abdominal ultrasound are useful if inflammatory or neoplastic disease is suspected
G. Fecal analysis: Parasites can cause CNS disease in young animals
H. Serology for viral or rickettsial diseases may be indicated
I. Immunofluorescence can be used to identify some viral diseases
J. Toxicology may be utilized to identify certain toxins

V. Neuroradiography and special imaging
A. Radiographs of the spine

1. Used to identify bony lesions, changes in intervertebral disc spaces
2. Provide minimal information in regard to spinal cord compression

B. Myelography
1. Contrast material is injected into the subarachnoid space
2. Useful for viewing extradural or intradural lesions causing spinal cord compression

C. Radiographs of the skull can identify fractures, foramen magnum problems, and tumors
D. Computed tomography (CT) provides excellent imaging of bony structures
E. Magnetic resonance imaging (MRI) provides excellent imaging of brain and spinal cord

VI. Cerebrospinal fluid (CSF) collection and analysis
A. CSF analysis is indicated if inflammation is suspected
B. CSF analysis is contraindicated if intracranial pressure is elevated
C. CSF collection is performed under general anesthesia. If a brain disorder is suspected, collect CSF at the cerebellomedullary cistern. For spinal cord disorders, collect CSF at the lumbar space
D. CSF analysis
1. Gross examination
a. CSF should normally be clear and colorless
b. CSF is turbid in inflammation
c. Pink color indicates blood contamination; yellow-orange color indicates breakdown of hemoglobin from previous hemorrhage or severe elevation in CSF protein
2. Cytology
a. Suppurative meningitis is characterized by an increase in neutrophils and indicates bacterial encephalitis, meningioma, vasculitis in young dogs or feline infectious peritonitis (FIP) in cats
b. Mixed inflammation is characterized by an increase in a mixed population of cells and usually indicates fungal, protozoal, or idiopathic encephalitis. It may be seen in chronic bacterial infections
c. Nonsuppurative inflammation is indicative of immune-mediated encephalitis, rickettsial infection, and some viral infections
d. Eosinophilic inflammation is secondary to immune-mediated encephalitis, fungal or protozoal infections, and parasite migration
e. Increased red blood cells (RBCs) may be due to contamination during the CSF tap but can also be due to hemorrhage due to trauma. Erythrophagocytosis is an indication of previous hemorrhage
f. Other cells or organisms identified include tumor cells cryptococcal or fungal organisms, distemper inclusions, bacteria, or rickettsial organisms
3. Protein concentration is normally low in CSF. Disorders that increase CSF protein include encephalitis, meningitis, neoplasia, chronic neurodegenerative conditions, and trauma
4. CSF can be tested for antibodies against infectious agents

VII. Electroencephalography (EEG)
A. An EEG is useful with corticocerebral lesions. Sedation is usually required to minimize movement
B. The major disadvantage is that no information is gathered regarding cause

VIII. Brainstem auditory evoked response tests hearing

IX. Electrodiagnostic examination of the motor unit
A. Needle electromyography (EMG) gives information about motor unit innervation and muscle membrane ion conductance
B. Nerve conduction studies measure the action potential conduction velocity between points along a motor nerve
C. Repetitive nerve stimulation is useful in neuromuscular junction diseases
D. Tensilon or edrophonium chloride test. Intravenous (IV) administration transiently alleviates signs of myasthenia gravis

BRAIN AND CRANIAL NERVE DISORDERS

I. Clinical signs
A. Brainstem lesions
1. Cranial nerve dysfunction (CN3-CN12) is common
2. Clinical signs involving facial expression (CN7) and mastication (CN5) are common
3. Head tilt, circling, and falling are signs of vestibular nuclei damage
4. Ascending white matter tract injury causes ipsilateral conscious proprioceptive deficits
5. Descending UMN injury causes tetraparesis or paralysis
6. Severe brainstem lesions result in altered consciousness and can affect cardiovascular and respiratory regulation

B. Cerebellar lesions
1. Incoordination during voluntary movements
2. Truncal swaying and a wide-based stance
3. Intention tremor of the head
4. The menace response is absent ipsilaterally
5. Mild pupil dilation may be present ipsilaterally
6. Vestibular signs and opisthotonus may be present
7. Mental status is usually normal

C. Forebrain lesions
1. Seizures, personality changes, and dementia can occur with both diffuse and focal disorders
2. Diffuse disorders may cause conscious proprioceptive deficits, stupor, coma, absent response to pain, generalized ataxia, and bilateral miosis
3. Focal disorders may cause circling, contralateral conscious proprioceptive deficits, contralateral facial sensory deficits and weakness. Focal diencephalic lesions can cause lethargy, altered mentation, or circling. Head and neck pain can result from structural lesions

D. Manifestations of systemic metabolic alterations
1. Signs are usually diffuse, with alteration of mental status
2. Seizures may also be seen

E. Herniation from space-occupying brain lesions
1. If there is transtentorial herniation, clinical signs include extensor rigidity in the limbs, and stupor or coma
2. If there is foramen magnum herniation, clinical signs include opisthotonus, thoracic limb rigidity, and severe alterations in respiration

II. Neoplasia usually affects middle-aged and older animals

A. Causes
1. The most common primary tumors in the dog are meningioma and glioma (astrocytoma, glioblastomas, oligodendrogliomas, ependymomas, and choroids plexus papillomas/carcinomas)
a. Meningiomas occur mostly in dolichocephalic breeds, and gliomas occur mostly in brachycephalic breeds
b. Meningiomas are often located in the olfactory or frontal lobe
2. The most common primary tumor in the feline is meningioma; frequently multiple
3. Secondary brain tumors occur from hematogenous spread or extension from surrounding tissues
a. Tumors with hematogenous spread are hemangiosarcoma, malignant melanoma, mammary adenocarcinoma, and pulmonary adenocarcinoma
b. In the dog, secondary lymphoma occurs with the multicentric form. Multicentric malignant histiocytosis can also invade the CNS
c. Tumors invading by extension are usually nasal adenocarcinoma, pituitary macroadenoma or carcinoma, and bony tumors of the skull

B. Clinical signs depend on the location and type of tumor
1. Signs may be vague, with irritability, changes in behavior, pacing, and lethargy
2. Signs may arise from obstruction of CSF flow or from herniation. Vestibular symptoms, or cranial nerve signs may also be seen

C. Diagnosis
1. Laboratory testing is used to rule out other causes of nervous system signs. Adrenal function testing may reveal the presence of pituitary macroadenoma
2. Ophthalmologic examination should be done to check for papilledema, which is a sign of increased intracranial pressure
3. EEG may detect brain lesions or epilepsy
4. Radiography may reveal some bony lesions or metastasis
5. CT and MRI are used for more precise definition of tumors
6. CSF analysis is useful to distinguish inflammation from neoplasia

D. Treatment
1. Corticosteroids are used to treat edema and meningioma
2. Mannitol is used in those with increased intracranial pressure. Furosemide will help prolong the effects of mannitol
3. Phenobarbital with or without potassium bromide is indicated if seizures are present
4. Lomustine may be beneficial in treating gliomas and meningiomas
5. Surgery may be possible, depending on location
6. Radiation therapy consistently prolongs survival, especially for meningiomas and canine pituitary tumors

III. Inflammatory brain diseases

A. Infectious meningoencephalitis (more common in cats)
1. Many agents cause inflammatory brain disease, including viral, fungal, rickettsial, and protozoal agents
2. Diagnostic testing includes complete blood cell count (CBC), chemistry profile, urinalysis, radiographs, and ophthalmological evaluation
a. CSF analysis may be beneficial; CSF titers can be determined
b. Cytologic evaluation of skin lesions, exudates, and aspirates may identify a pathogen
3. Treatment depends on the underlying cause
a. Usually requires prolonged therapy
b. Most effective if parenteral antibiotics are administered

B. Idiopathic inflammatory brain disorders (more common in dogs)
1. Granulomatous meningoencephalomyelitis (GME)
a. GME is an immune-mediated condition with perivascular accumulations of lymphocytes, plasma cells, and histiocytic cells. There are disseminated, focal, and optic forms
b. Clinical signs
(1) Usually affects toy and small breeds between 1 and 8 years of age
(2) Vestibular signs are common; CN5 and CN7 deficits may be seen. Fever, lethargy, and anorexia may be the only clinical signs seen initially
c. Diagnosis is by exclusion. A marked mononuclear cell inflammation is seen in the CSF
d. Prednisone may cause remission
e. Relapses are common, and patients may become refractory to treatment
2. Necrotizing encephalitis
a. Similar to GME and may have an immune-mediated component. Multifocal, necrotic, cavitating lesions are commonly seen
b. Clinical signs include seizures, dementia, blindness, neck pain, and ataxia. Necrotizing encephalitis usually occurs in toy breed between 9 months and 5 years of age
c. Diagnosis is by exclusion of GME, infectious disease, and neoplasia. A marked mononuclear cell inflammation is seen in the CSF

d. Treat with prednisone and anticonvulsants. The prognosis is poor

3. Generalized idiopathic tremors (Little White Shaker syndrome)
 a. Occurs in toy and small-breed dogs with white coat color; other breeds can be affected. Usually affects dogs younger than 6 years
 b. Clinical signs include coarse body tremors that worsen with stress, exercise, or handling
 c. Differential diagnosis includes neurotoxin exposure, seizures, and inflammatory brain diseases
 d. Treatment is with diazepam and prednisone. The prognosis is good, although relapses may occur

IV. Vascular diseases
 A. Vascular encephalopathies
 1. Typically affects older animals. Ischemia or infarction occurs as a result of thrombosis of a blood vessel secondary to an underlying condition (e.g., hypertension, atherosclerosis, hyperviscosity, tumor emboli)
 2. Clinical signs are usually asymmetrical and cause signs of forebrain disease or vestibular disease
 3. Diagnosis is by diagnosing the underlying disorder; MRI is useful in determining the extent of the ischemia or hemorrhage
 4. Treatment of the underlying condition is important; anticonvulsants or mannitol therapy to treat brain edema may be necessary
 B. Feline ischemic encephalopathy
 1. Occurs in young to middle-aged cats, with a higher incidence in late summer. It is caused by a cerebral infarction of the middle cerebral artery
 2. Clinical signs are of cerebral dysfunction. Seizures may be the only sign; clinical signs may improve over months
 3. Rule out other causes of vascular disease and cerebral disease; MRI may show cerebral edema
 4. Anticonvulsant therapy may be needed; prednisone is not effective
 C. Necrotizing vasculitis
 1. Occurs in young (i.e, 3 to 18 months old) beagles, Bernese mountain dogs, and German shorthaired pointers. Probably immune-mediated
 2. Clinical signs of meningitis such as neck pain, stiffness, and fever are common
 3. CSF analysis shows an increase in neutrophils
 4. Treat with immunosuppressive doses of corticosteroids. Prognosis is fair to guarded
 D. Infectious cause of vasculitis
 1. Caused by fungal, protozoal, viral, or rickettsial agents
 2. Head and neck pain are common, and edema results in brain swelling. Cranial nerve deficits and vestibular signs may be present
 3. Characteristics of the CSF will depend on the underlying cause
 4. Treatment and prognosis depend on the underlying cause

V. Brain trauma
 A. Trauma can cause an increase in intracranial pressure leading to bradycardia, hypertension, and pulmonary edema. A delayed consequence is epilepsy
 B. Focal signs reflect the region of the brain involved. Progression occurs within the first 24 to 48 hours after an injury, so a neurologic examination should be performed every few hours
 C. An EEG can be used to localize the brain damage
 D. Correct any life-threatening symptoms; elevation of the head will help maintain cerebral blood flow and enhance CSF resorption. Hyperventilation will stimulate vasoconstriction and decrease intracranial pressure
 1. Methylprednisolone sodium succinate is beneficial if administered immediately following the trauma
 2. Mannitol and furosemide may be beneficial if there is brain edema
 3. Hypertonic saline with hetastarch should be used in those with hypovolemic shock and head trauma
 4. Use diazepam to control seizures
 5. Monitor fluid therapy

VI. Metabolic brain encephalopathies
 A. The cerebrum is most often affected
 B. Clinical signs include altered behavior, dementia, and seizures
 C. Causes include osmotic and ionic imbalances, acid-base imbalance, hypoglycemia, hypoxia, renal failure, and hepatic encephalopathy

VII. Thiamine deficiency
 A. Deficiency in vitamin B_1 is caused by improperly formulated diets (especially all fish diets) or prolonged anorexia. Cats are more frequently affected
 B. Clinical signs include weight loss, head and neck ventroflexion, ataxia, extensor rigidity, opisthotonus, coma, mydriasis, blindness, seizures, and sudden death
 C. Rule out other causes of clinical signs
 D. Treat with parenteral thiamine; supplement with B vitamins for at least 2 weeks. Prognosis is good if therapy is initiated early

VIII. Neurotoxins
 A. Lead poisoning
 1. Caused by ingestion of lead-containing paint chips, plaster board, and other building materials. Chronic exposure may cause a chronic toxicity
 2. Clinical signs include vomiting, diarrhea, anorexia, abdominal pain, behavior changes, seizures, pica, vocalization, and blindness
 3. Nucleated RBCs and basophilic stippling are noted on CBC. An increase in blood lead suggests lead poisoning
 4. Treat with a chelating drug (EDTA; D-penicillamine; 2,3-dimercaptosuccinic acid). Give anticonvulsants if needed; treat cerebral edema if present. The prognosis is fair to good

B. Metaldehyde poisoning
 1. Metaldehyde is a molluscide and produces severe metabolic acidosis if ingested
 2. Clinical signs include seizures, tremors, depression, salivation, vomiting, and diarrhea. Hepatic failure occurs several days after ingestion
 3. Diagnosis is based on history and clinical signs
 4. Treat with gastric lavage and activated charcoal if within 2 hours of ingestion. Sodium bicarbonate is used to treat acidosis; anticonvulsants may be needed. Prognosis is poor

C. Methylxanthine toxicosis (caffeine, theobromine)
 1. Dark chocolate contains more caffeine and theobromine than does milk chocolate; ingestion of as little as 1 ounce of baker's chocolate per kilogram of body weight may be lethal
 2. Clinical signs include tachycardia, cardiac arrhythmias, vomiting, polyuria, polydipsia, respiratory paralysis, cyanosis, seizures, muscle tremors, ataxia, and coma
 3. Diagnosis is based on history and clinical signs
 4. Treat with activated charcoal, promote diuresis, treat cardiac arrhythmias and seizures. Prognosis is fair if treatment is started early

D. Organophosphate and carbamate poisoning
 1. Actylcholinesterase is inhibited, so acetylocholine is not broken down at muscarinic and nicotinic sites of the autonomic and somatic nervous systems
 2. Clinical signs include salivation, vomiting, diarrhea, miosis, bradycardia, muscle tremors, weakness, exercise intolerance, respiratory paralysis, hyperactivity, and seizures
 3. Diagnosis is based on history and clinical signs
 4. Treat by inducing vomiting if ingestion has occurred within the previous 2 hours and there are no clinical signs. Give anticonvulsants if necessary; bathe if exposure is on the skin. Give atropine and pralidoxime chloride; provide support with IV fluids, nutritional support, padded bedding. The prognosis is good if treatment is early

E. Ivermectin toxicity
 1. Normally the blood-brain barrier prevents ivermectin from entering the CNS. A P-glycoprotein pump defect in some collies, Shetland sheepdogs, Australian shepherds, and Old English sheepdogs allows ivermectin to enter the brain. A single oral dose can be neurotoxic if this defect is present
 2. Clinical signs include ataxia, muscle tremors, tetraparesis, and coma
 3. Diagnosis is based on history, breed, and clinical signs
 4. Treatment is supportive. Prognosis is good, but recovery can take weeks

F. Metronidazole toxicity
 1. Toxicity may be seen in the dog and cat after more than 7 days of therapy with metronidazole
 2. Clinical signs include severe ataxia, nystagmus, opisthotonus, seizures, and a crouched posture in the pelvic limbs
 3. Diagnosis is based on history, clinical signs, and the absence of other disease
 4. Discontinue administration of metronidazole, and clinical signs usually resolve over 1 to 2 weeks

G. Bromethalin poisoning
 1. Bromethalin is present in rodenticides and uncouples phosphorylation
 2. Clinical signs include hyperexcitability, muscle tremors, seizures, limb rigidity, nystagmus, depression, ataxia, paresis, loss of deep pain, and paraplegia
 3. Diagnosis is based on history and clinical signs
 4. Treat by inducing vomiting; give activated charcoal if less than 2 hours after ingestion. Provide supportive care, and give anticonvusants if needed. Prognosis is poor

H. Ethylene glycol poisoning

IX. Congenital malformations and anomalies

A. Hydrocephalus
 1. Congenital disorder characterized by an accumulation of CSF within the brain and may accompany other congenital malformations
 2. Clinical signs include head pressing, dementia, changes in behavior, seizures, altered consciousness, ataxia, and visual deficits. An open fontanelle with ventrolateral strabismus is often present. Breeds commonly affected include Pomeranian, toy poodle, Maltese, Yorkshire terrier, Chihuahua, Manchester terrier, Cairn terrier, shih-tzu, English bulldog, Boston terrier, Pekingese, Lhasa apso and others. Signs are usually seen in dogs less than 1 year of age
 3. The primary differential diagnosis is hepatic encephalopathy, encephalitis, and toxin exposure
 4. Treatment with corticosteroids may be beneficial short-term. Mannitol is indicated if there is an elevation of intracranial pressure. Anticonvulsants should be given for seizures

B. Lissencephaly
 1. Lissencephaly is the absence of cerebral cortex convolutions and thinned white matter. It is inherited in the Lhasa apso, wirehaired fox terrier, and Irish setter. Some may have concurrent cerebellar hypoplasia
 2. Clinical signs include behavior changes, dementia, seizures, and visual deficits. Clinical signs are present at birth or within the first year of life
 3. There is no specific treatment; treat with anticonvulsants if needed

C. Congenital arachnoid cysts
 1. There is cystic accumulation of CSF in the subarachnoid space. These can slowly enlarge and cause compression of adjacent neural tissue
 2. Clinical signs include seizures, paresis, behavior changes, and cranial nerve deficits. Signs appear in young adults
 3. Diagnosis is by visualization on MRI or CT
 4. Treatment is by surgical fenestration of the cyst wall

D. Cerebellar hypoplasia in cats
 1. Caused by exposure of kittens in utero to panleukopenia infection
 2. Clinical signs including severe ataxia, intention tremors, falling, head bobbing, and loss of menace response are observed as soon as kittens start to walk
 3. Diagnosis is based on clinical signs
 4. There is no treatment

E. Cerebellar hypoplasia in dogs
 1. May be secondary to postnatal herpesvirus infection, but most cases have a genetic base. Affected breeds include the chow chow, Airedale terrier, Irish setter, wirehaired fox terrier, Boston terrier, bull terrier, Weimaraner, dachshund, and Labrador retriever
 2. Clinical signs are nonprogressive and include ataxia, disequilibrium, falling, intention tremors, and an absent menace response
 3. Treatment is not available

X. Degenerative brain disease

A. Cerebellar abiotrophies
 1. The cerebellum develops normally but is followed by premature degeneration and cell death. It is autosomal recessive in some breeds
 2. Clinical signs include intention tremor and progressive ataxia. Dogs are normal at birth, but clinical signs start between 4 and 10 weeks of age
 3. Rule out other causes of progressive cerebellar disease
 4. There is no treatment. The prognosis is poor

B. Multiple neuronal abiotrophies
 1. Cell loss or chromatolytic changes in multiple areas of the brain. Breeds affected include the Cairn terrier, Kerry blue terrier, miniature poodle, cocker spaniel, and rough-coated collie
 2. Clinical signs are primarily cerebellar in Kerry blue terriers, rough-coated collies, and Cairn terriers. Cocker spaniels have signs of both cerebellar and cerebral degeneration; miniature poodles have cerebellovestibular signs. Onset of signs is usually between 4 and 16 weeks of age
 3. Differential diagnosis includes lysosomal storage disease, and inflammatory CNS disease
 4. There is no treatment

C. Multisystem neuroaxonal dystrophy
 1. An inherited error of metabolism that results in swellings along regions of the axon. Breeds affected include the rottweiler, Jack Russell terrier, Chihuahua, bullmastiff, Labrador retriever, collie-sheepdog mixed breed, and domestic shorthaired cat
 2. Clinical signs are cerebellar in origin; cerebral signs are seen in the Labrador retriever
 3. Differential diagnosis includes other congenital cerebellar disorders, or inflammatory, metabolic, or toxic disorders
 4. There is no treatment

D. Cognitive dysfunction
 1. Neurodegenerative disorder of the forebrain with gradual onset and progression of cognitive loss in older dogs (greater than 11 years of age). Cortical atrophy and amyloid plaques are common. Decreased levels of norepinephrine and dopamine have been observed in the frontal cortex
 2. Clinical signs include decreased social interaction, staring, wandering, getting lost, loss of house training, and altered sleep cycles
 3. Diagnosis is based on history and clinical signs
 4. Treat with selegiline, which inhibits the breakdown of dopamine and norepinephrine. Modify the environment, and pay attention to nutrition, feeding, and exercise

XI. Cranial nerve disorders

A. Idiopathic disorders
 1. Trigeminal neuritis
 a. Etiology is unknown. Affects middle-aged dogs
 b. Clinical signs include inability to close the mouth and difficulty in chewing food
 c. Diagnosis is based on history of acute mandibular paralysis
 d. Treatment is supportive; corticosteroid therapy is not beneficial
 2. Idiopathic facial paralysis or palsy
 a. Causes
 b. Clinical signs include a unilateral facial droop, decreased tear production, and inability to blink. Food, water, and saliva fall out of the mouth. Cocker spaniels have an increased incidence
 c. Diagnosis is by ruling out other causes of facial paralysis
 d. There is no treatment
 3. Canine idiopathic vestibular disease
 a. Cause is unknown; affects older dogs and young adult cats typically
 b. Clinical signs include head tilt, circling, falling, nystagmus, and anorexia. Signs gradually improve with time
 c. Diagnosis is by ruling out other causes of clinical signs
 d. Treatment is supportive until clinical signs resolve (usually within a few weeks)

B. Hypothyroidism
 1. Usually causes vestibular signs, but may also affect CN7 and CN10
 2. Clinical signs are typically signs of vestibular disease
 3. Diagnosis is by ruling out other causes of vestibular disease, and documentation of hypothyroidism
 4. Treat with thyroid supplementation

C. Neoplasia
 1. CN5 neoplasia
 a. Neurofibromas or schwannomas are most common in middle-aged to older dogs
 b. Slow progression of temporal and masseter muscle atrophy followed by facial sensory loss is observed
 c. MRI is the diagnostic method of choice
 d. Surgery is difficult; radiation therapy may slow progression

2. CN8 neoplasia
 a. Neurofibromas or meningiomas may affect CN8. In addition, other tumors may extend into or invade the nerve
 b. Clinical signs include vestibular signs, Horner syndrome, and other cranial neuropathies
 c. MRI is the diagnostic method of choice
 d. Usually not possible to remove the tumor

D. Congenital sensorineural deafness
1. Caused by postnatal cochlear hair cell and spiral ganglion degeneration; occurs in many dog breeds. Also occurs in white cats with blue eyes
2. Clinical signs include unilateral or bilateral deafness in very young puppies
3. There is no treatment

SEIZURES

I. Definitions
A. An epileptic seizure is caused by abnormal activity in the cerebral cortex
B. Epilepsy is the chronic disorder characterized by recurrent epileptic seizures
C. Status epilepticus is a continuous seizure that lasts more than 30 minutes
D. Clinical stages
1. Prodrome stage is the period before the onset of a seizure. Altered behavior may be noted during this stage
2. The aura is the initial phase of a seizure
3. The ictal phase is the manifestation of the seizure
4. The postictal phase is the period immediately after the seizure. Altered behavior may be noted

E. Seizure types
1. Generalized convulsions are most common
2. Automotor seizures (psychomotor seizures) are characterized by abnormal behaviors and motor signs such as aggression, howling, excessive barking, fly-biting behavior
3. Focal seizures originate from a focal lesion in the cerebral cortex. Focal motor seizures may manifest as facial twitching, or twitching of limb muscles
4. Clustered seizures refers to two or more seizures within 24 hours

II. Causes
A. Normally there is a balance between excitatory and inhibitory neurotransmission. With epilepsy, there is more excitatory neurotransmission
B. Idiopathic epilepsy implies that there is no underlying brain lesion present
C. Secondary epilepsy occurs owing to a structural lesion in the brain
D. Cryptogenic epilepsy is due to a presumed structural lesion that has not been identified (previous head trauma, hypoxic events, vascular events, postencephalitis)

III. Clinical Signs
A. Epileptic seizure should be suspected if there is an incident of a sudden onset of abnormal behavior and/or motor activity, followed by a change in behavior or orientation
B. Obtain a thorough history. Include information on vaccination status, pedigree, travel history, medications given, and previous medical and surgical problems
C. Obtain as much data about seizure episodes as possible. Include duration, time between seizures, type of seizures, and behaviors surrounding the seizure
D. Evaluate current behaviors and document changes

IV. Diagnosis
A. Dogs
1. In dogs younger than 1 year, seizures are usually secondary to developmental, metabolic, or inflammatory disorders
2. In dogs between 1 and 5 years of age, seizures are usually idiopathic, although some may result from a congenital disorder
3. If older than 5 years of age, seizures are usually due to structural disorders (brain tumor), or metabolic diseases

B. Cats: Idiopathic epilepsy is rare; almost all cats have an underlying cause of seizures
C. Diagnostic approach
1. Idiopathic epilepsy is likely if:
 a. There is greater than 4 weeks between seizures
 b. The dog is a large breed dog
 c. Seizures start between the ages of 1 and 5 years
2. Secondary epilepsy is likely if:
 a. There is less than 4 weeks between seizures
 b. The first seizure is a focal seizure
 c. Seizures start before 1 year of age or after 7 years of age
 d. There is an abnormal neurological examination
3. Seizures attributable to a metabolic disorder are likely if:
 a. There are signs of systemic illness
 b. There is less than 4 weeks between seizures

D. Diagnostic testing
1. Minimum database includes CBC, biochemistry profile, urinalysis, thoracic radiographs, and blood pressure. Serum bile acids may be warranted if portosystemic shunt is suspected
2. MRI is best for diagnosing an intracranial disorder or neoplasia
3. CSF examination should be performed if an inflammatory process is suspected
4. Other diagnostic tests may be indicated if toxins, insulinoma, or infectious diseases are suspected

V. Treatment
A. The goal of therapy is to decrease or eliminate seizure activity with minimal side effects of medication
B. Treatment should be started when there have been two or more seizures within 6 months, there have been two or more cluster seizures within 12 months, there has been an episode of status

epilepticus, there is evidence of an intracranial disease, or a seizure has occurred within one week of a trauma

C. Phenobarbital administration
 1. Maximal absorption occurs within 4 to 8 hours after oral administration
 2. Most is metabolized by the liver
 3. Phenobarbital induces the hepatic P450 system in the dog but not the cat. This will decrease the elimination half-life in the dog
 4. IV treatment can achieve therapeutic concentrations rapidly
 5. Serum monitoring
 a. Trough concentrations of serum phenobarbital should be monitored after reaching a steady state
 b. After starting treatment, monitor at 2 weeks, 45 days, 3 months, 6 months, and 1 year. Then monitor at 6-month intervals
 c. Monitor if status epilepticus or cluster seizures occur or if there are more than two seizures between monitoring times
 d. Adjust dosage based on desired concentration and actual concentration, not according to body weight
 e. If a peak level measurement is desired, monitor at 4 to 6 hours post-pill
 f. Monitor CBC and chemistry profile at least every 6 months
 6. Adverse effects
 a. Sedation and lethargy commonly occur, but this is usually transient and dissipates after a few weeks
 b. Polyuria, polydipsia, and polyphagia may occur. Weight gain is also common
 c. Alkaline phosphatase commonly elevates, and thyroid hormone concentrations may be depressed
 d. Hepatotoxicity may develop, and the efficacy over time may be gradually diminished

D. Refractory epilepsy
 1. Seizures have continued or worsened over 3 months even though phenobarbital concentrations appear adequate
 2. Status epilepticus has occurred, or hepatotoxicity is present

E. Bromide therapy
 1. Oral bromide is used in addition to phenobarbital and decreases the number and severity of seizures in many dogs
 2. Monitor bromide levels at 1 month, 3 months, and 6 months after starting therapy. Then monitor every 6 months after that
 3. Bromide can be used without phenobarbital if there is hepatic disease, if there have been no seizures for more than a year, or the quality of life is unacceptable on both phenobarbital and bromide, and there have been no seizures for more than 3 months
 4. Bromide therapy is not recommended in cats due to a high prevalence of respiratory problems

F. New antiepileptic drugs
 1. Felbamate is used alone
 2. Gabapentin is used in dogs with hepatic disease. Also used in cats

G. Drugs not used for routine therapy in the dog
 1. Phenytoin (Dilantin) causes hepatotoxicity and has very rapid elimination
 2. Diazepam (Valium) can cause withdrawal seizures, and tolerance develops very quickly

H. Hospital emergency treatment for seizures
 1. Emergency therapy should be given if status epilepticus is present, if a single seizure lasts more than 5 minutes, if there is more than one seizure per hour, or more than 3 seizures per day
 2. Use diazepam to stop seizure activity and a long-acting drug to prevent further seizures

I. At home emergency treatment for seizures
 1. Diazepam is rapidly absorbed when given rectally
 2. Administer when a seizure first starts, up to 3 times per day

SPINAL CORD DISORDERS

I. Causes
 A. Anomalies are usually recognized when the animal starts to walk. Some worsen with time and cause progressive worsening of clinical signs
 B. Degenerative disorders may be inherited, including lysosomal storage disorders, spinal muscular atrophy, and hereditary ataxia. Other degenerative disorders are age-related and include cervical spondylomyelopathy, intervertebral disc disease, lumbosacral stenosis, and mucopolysaccharidosis in cats
 C. Trauma can be from an external source (hit by car) or internal source (disc herniation)
 D. Inflammation or infection
 1. Bacterial infection is usually secondary to infection of surrounding tissues
 2. Viral infection includes rabies, canine distemper virus, FIP, and feline immunodeficiency virus (FIV)
 3. Fungal myelitis occurs with cryptococcosis, blastomycosis, histoplasmosis, and coccidiodomycosis
 4. Rickettsial causes include ehrlichiosis and Rocky Mountain spotted fever
 5. Protozoal causes include *Neospora caninum*, and toxoplasmosis
 E. Immune-mediated disorders occur in young dogs (commonly boxers), and signs are typically neck stiffness, hyperesthesia and fever. GME is also an immune-mediated disorder
 F. Toxins include strychnine and tetanus
 G. Vascular disorders can result in ischemia of the spinal cord with dysfunction
 H. Neoplastic causes include astrocytoma, ependymoma, hemangiosarcoma, lymphoma, and other tumors. Tumors can be intramedullary or extramedullary

II. Clinical signs
 A. Hyperpathia is the exaggerated response to a painful stimulus. Hyperpathia occurs when nerve

roots or dura adjacent to the spinal cord are involved
B. Proprioceptive deficits and ataxia occur early in spinal cord disease
1. Injury to CP tracts causes knuckling
2. Injury to unconscious proprioception (UP) tracts causes ataxia in limbs caudal to the lesion
C. Paresis (weakness) can result from injury to UMN or LMN tracts
1. UMN injury causes weakness in limbs caudal to the lesion, and LMN injury causes weakness in limbs at the level of the injury
2. UMN injury causes increased extensor muscle tone when recumbent
3. LMN injury causes decreased spinal reflexes, decreased muscle tone, and muscle atrophy
D. Nociceptive (pain) loss
1. Injury to ascending nociceptive tracts in the spinal cord results in depressed or absent pain from stimuli caudal to the injury
2. Lack of deep pain sensation indicates severe spinal cord injury
E. CP loss occurs first, followed by UP loss, UMN, then nociceptive loss as lesions worsen
F. Intramedullary lesions cause symmetrical clinical signs; extramedullary lesions cause asymmetrical signs that are usually ipsilateral to the lesion

III. Diagnosis
A. History: Progression of symptoms, signalment, and nature of onset are most important
B. Lesion localization by evaluation of clinical signs is important as some diseases target specific areas of the spinal cord
C. Minimum database includes CBC, biochemistry profile, and urinalysis to assess overall health. Specialized tests may be warranted based on findings
D. Electrodiagnostic tests such as EMG, nerve velocity studies, or nerve root studies may be helpful but require referral to a specialist
E. Imaging techniques
1. Plain spinal radiography is good for evaluation of bony lesions but does not give good information regarding spinal cord compression
2. Myelography may be useful but is invasive and requires longer anesthesia times
3. MRI is useful for imaging the spinal cord and other soft tissues
4. CT is preferred if bony lesions are being evaluated
F. CSF analysis is the test of choice for diagnosing inflammatory spinal cord disease

IV. Treatment
A. Medical therapy
1. Degenerative disorders causing compression of the spinal cord are treated primarily with glucocorticosteroids at antiinflammatory doses
2. Spinal cord trauma should be treated immediately after injury with large doses of corticosteroids. Glucocorticosteroids are beneficial for about the first 2 to 3 days
3. Infection should be treated with antibiotics that cross the blood-brain barrier, such as trimethoprim-sulfonamide, refampin, metronidazole, penicillins, quinolones, clindamycin, and cephalosporins. Discospondylitis is usually caused by *Staphylococcus* but may be caused by other organisms. Treat with an appropriate antibiotic
4. Immune-mediated disorders are treated with immunosuppression. Prednisone is used in combination with other immunosuppressive agents
5. Toxicities, such as tetanus, are treated with a combination of penicillin, tetracycline, or metronidazole with tetanus antitoxin, chlorpromazine, diazepam, and phenobarbital
6. Neoplasia is difficult to treat as most chemotherapeutic agents do not cross the blood-CSF barrier. Lomustine does penetrate the CNS and can be used in conjunction with prednisone to treat CNS lymphoma
B. Surgical treatment
1. The primary goal is to decompress the spinal cord and stabilize the vertebral column
2. The decision to perform surgery is based on the progression of clinical signs and the likelihood that surgery will be beneficial
3. Surgery is most beneficial if it is performed early in the course of the disease
C. Nursing care is very important and includes thermal applications of cold and hot packs, muscle massage, limb manipulations, hydrotherapy, frequent evacuation of the bladder, padded bedding, and daily baths

V. Prognosis
A. Based on clinical signs
1. The more severe the clinical signs, the poorer the prognosis
2. The longer the duration of spinal cord injury, the poorer the prognosis
B. Based on cause
1. Anomalies have a nonprogressive course, and prognosis depends on the extent of injury
2. Degenerative disorders have a guarded or poor prognosis
3. Trauma
a. With fractures, if the spinal cord is intact, surgery can be beneficial if performed within a few hours of injury
b. Extramedullary compressive lesions have a better prognosis than intramedullary lesions
4. Infection has a guarded prognosis unless a specific cause can be identified and treated. Discospondylitis has a fair to good prognosis if treatment is instituted early
5. Meningitis and myelitis
a. Immune-mediated meningitis has a good prognosis if treated appropriately
b. Granulomatous encephalitis has a guarded to poor prognosis

6. The prognosis for vascular disorders depends on the severity of the neurologic deficits
7. Neoplasia is associated with a poor prognosis overall

PERIPHERAL NERVE DISORDERS

I. *Neuropathy* refers to functional disturbances in the peripheral nervous system. *Polyneuropathy* refers to involvement of several nerves
II. Clinical signs typically include weakness and muscle atrophy. Self-mutilation may occur
III. Principles of diagnosis
 A. History and physical examination are most important
 B. Elevations of creatine phosphokinase, lactic dehydrogenase, and aspartate aminotransferase suggest a muscle disorder
 C. Needle EMG can record activity in skeletal muscle
 D. Muscle and nerve biopsies may help with the diagnosis
IV. Treatment is typically supportive
 A. Prevent decubital ulcer formation
 B. Prevent tendon and muscle contraction with physical therapy
 C. Maintain nutrition
 D. Make sure that there is complete evacuation of the urinary bladder
V. Specific peripheral nerve disorders
 A. Anomalous, inherited, and congenital disorders
 1. These disorders are noted prior to 1 year of age, and diagnosis is based on clinical signs and signalment. An inherited or congenital disorder should be suspected in any young dog or cat with signs of peripheral nerve disease
 2. Specific breeds that may be affected by recognized inherited disorders include German shepherd dogs, Tibetan mastiffs, boxers, pointers, longhaired dachshunds, Brittanys, rottweilers, Leonberger dogs, Alaskan malamutes, dalmatians, golden retrievers, Birman cats, and Norwegian Forest cats
 3. Globoid cell leukodystrophy is caused by a deficiency of β-galactocerebrosidase
 4. Glycogen storage disease in Norwegian Forest cats occurs due to a deficiency in a glycogen branching enzyme
 5. Other storage diseases affecting peripheral nerves include hyperchylomicronemia in cats, Niemann-Pick disease, and GM_2-gangliosidosis
 B. Metabolic and endocrine disorders
 1. Diabetes mellitus can cause limb weakness (more pronounced in the pelvic limbs)
 2. Hypothyroidism can be associated with weakness, muscle wasting, and reduced spinal reflexes
 C. Nutritional disorders are uncommon. Vitamin B deficiency can induce neuropathy
 D. Neoplastic disorders
 1. Nerve sheath tumors and lymphoma are most common, producing signs of a neuropathy
 2. Insulinomas have also been associated with neuropathy
 E. Inflammatory and immune-mediated disorders
 1. *Toxoplasma gondii* and *Neospora caninum* can cause inflammation of peripheral nerves
 2. Acute polyradiculoneuritis (coonhound paralysis) is a common peripheral nerve disorder
 a. Frequently observed in hunting dogs 1 to 2 weeks after exposure to a raccoon
 b. Pelvic limb weakness rapidly progresses to tetraparesis. Response to pain is often exaggerated
 c. Differential diagnosis includes botulism, tick paralysis, myasthenia gravis, and protozoal infection
 d. Treat with supportive care
 F. Idiopathic disorders can affect any breed of dog or cat, causing insidious or acute onset of weakness
 G. Traumatic injury
 1. Common cause of weakness
 2. Prognosis is better when the nerve is injured close to the muscle it innervates
 3. Brachial plexus avulsion is common in road traffic injuries or when animals jump from moving vehicles
 a. Treat with physical therapy to prevent muscle contraction. Prevent abrasions
 b. Regrowth of injured nerves may take months. Amputation should be considered if there is self-mutilation or little return to function after 6 months

MUSCLE AND NEUROMUSCULAR JUNCTION DISORDERS

I. Causes
 A. Hereditary disorders
 1. Canine dystrophin-deficient muscular dystrophy
 a. Similar to Duchenne muscular dystrophy of humans
 b. Most commonly in males
 c. Breeds predisposed include golden retriever, Irish terrier, Samoyed, rottweiler, Japanese spitz, and Labrador retriever
 d. Evident by about 10 to 12 weeks of age, and clinical signs include stunted growth, weakness, muscle atrophy
 e. Serum creatine kinase levels are markedly elevated
 2. Feline dystrophin-deficient muscular dystrophy
 a. Lethal condition of young male cats
 b. Clinical signs include skeletal muscle hypertrophy, glossal hypertrophy and dysfunction, and excess salivation
 c. Serum creatine kinase levels are markedly elevated, and there is lack of dystrophin in skeletal muscles
 3. Other muscular dystrophies
 a. Muscular dystrophy with merosin (laminin α-2) deficiency has been reported in a mixed-breed dog and in several cats. Affected animals are young, with muscle weakness and atrophy. Serum creatine kinase is moderately elevated

b. Muscular dystrophy with sarcoglycan deficiency has been identified in a few breeds of dog. Serum creatine kinase concentration is markedly elevated, and there is an absence of sarcoglycan in skeletal muscle

4. Hereditary myopathy of Labrador retrievers
 a. Autosomal recessive
 b. Clinical signs include progressive muscle weakness, exercise intolerance, and gait abnormalities
 c. Varying morphologic features have been noted on muscle biopsies
5. Central core-like myopathy
 a. Great Danes
 b. Excitement causes episodes of body tremors and collapse
6. Nemaline rod myopathy has been reported in several cats and one dog. Characterized by mild weakness, tremors, reluctance to move, and progressive muscle atrophy. Nemaline rods are present within myofibers
7. Familial canine dermatomyositis
 a. Collies and Shetland sheepdogs. Autosomal dominant in collies
 b. Severe dermatitis on face, ears, extremities over bony prominences, and tail tip
 c. Inflammatory myopathy of masticatory muscles and muscles distal to elbow and stifle
8. Glycogen storage disorders
 a. Rare
 b. Muscle weakness is minor compared with other clinical symptoms
9. Myotonia congenital
 a. Chow chow and miniature schnauzers; also cats
 b. Clinical signs include difficulty rising, muscle stiffness, bunny-hopping gait; affects puppies
 c. DNA test available
10. Mitochondrial myopathy
 a. Clumber spaniels and Sussex spaniels with a pyruvate dehydrogenase deficiency
 b. Exercise intolerance with metabolic acidosis, excessive elevation of lactic acid and pyruvate
11. Hypertonicity syndrome
 a. Identified in Cavalier King Charles spaniel, English springer spaniel, soft-coated wheaton terrier, and border terrier
 b. In Cavalier King Charles spaniels, clinical signs appear between 3 to 7 months of age. Exercise or excitement precipitate pelvic and thoracic limb hypertonicity
 c. Treat with clonazepam
12. Congenital myasthenia gravis
 a. Jack Russell (Parson Russell) terriers, English springer spaniels, and smooth fox terriers
 b. Deficiency in muscle acetylcholine receptor

B. Acquired neuromuscular disorders
 1. Autoimmune disorders
 a. Acquired myasthenia gravis
 (1) Common in dogs, also occurs in cats
 (2) Associated with autoantibodies against nicotinic nicotinic acetylcholine receptors on postsynaptic membrane of neuromuscular junction. This leads to impaired neuromuscular transmission and weakness
 b. Masticatory muscle myositis selectively affects the masticatory muscles
 c. Extraocular muscle myositis is localized to extraocular muscles
 d. Polymyositis
 (1) Generalized inflammatory myopathy as a result of cell-mediated immunity
 (2) Associated with malignancies, systemic lupus erythematosus, and immune-mediated arthritis
 2. Metabolic disoders
 a. Lipid storage myopathy
 b. Malignant hyperthermia syndrome
 c. Electrolyte imbalances, particularly potassium and calcium
 d. Endocrine disorders such as hypothyroidism, hyperadrenocorticism, and hypoadrenocorticism
 e. Neoplastic disorders. Thymoma has been associated with myasthenia gravis and polymyositis
 f. Parasitic disorders (especially *Neospora caninum*, and *Ehrlichia canis*)
 g. Viral disorders (feline calicivirus, FIV)
 h. Toxic or drug-induced disorders (neurotoxins from ticks, *Clostridium botulinum* toxin, organophosphate insecticides)
 i. Ischemic disorders (thromboembolism and vascular occlusion)

II. Clinical signs
 A. Muscular weakness is the most common clinical sign
 B. Gait abnormalities
 C. Paralysis or paresis
 D. Localized signs such as regurgitation, dysphagia, dysphonia, dyspnea

III. Diagnosis
 A. History and physical examination are most important. Proprioception and pain are usually intact in motor unit disorders
 B. Perform routine laboratory tests to identify underlying disorders. Other tests such as lactate, thyroid hormone concentrations, adrenal function tests, ANA titer, and serologic tests may be indicated
 D. Specialized tests such as edrophonium chloride challenge test, electrodiagnostics, muscle biopsy, and carnitine quantification may be helpful
 E. Radiography should be performed to rule out underlying disorders such as megaesophagus, neoplasia, aspiration pneumonia, thymoma

IV. Treatment
 A. Generalized myasthenia gravis
 1. Anticholinesterase drugs are most commonly used for treatment
 2. Corticosteroids are used if there is a negative response to edrophonium chloride testing, and

anticholinesterase treatment does not improve muscle strength
 3. Azothioprine or cyclophosphamide can be used for refractory cases
 4. Management megaesophagus by feeding food and water with the animal in an upright position. Have animal remain upright for at least 10 minutes after feeding. Anticholinesterase drugs should be given 1 hour before feeding

B. Focal myasthenia gravis
 1. Manage by elevating food and water
 2. Lower doses of anticholinesterase drugs may control regurgitation

C. Immune-mediated inflammatory myopathies
 1. Masticatory muscle myositis: Treat with immunosuppressive doses of glucocorticoids
 2. Polymyositis: Treat with immunosuppressive doses of glucocorticoids
 3. Lipid storage myopathy: Treat with L-carnitine

Supplemental Reading

Fenner WR, March PA. Diagnostic approach to neurologic disease. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1233-1248.

Luttgen PJ, Cudden PA. Disorders of the spinal cord. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1294-1303.

March PA. Diseases of the brain and cranial nerves. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1249-1276.

Podell M. Seizures. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1277-1293.

Shell LG. Peripheral nerve disorders. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1304-1314.

Shelton GD. Disorders of muscle and neuromuscular junction. In Birchard SJ, Sherding RG, eds. *Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1315-1324.

20 CHAPTER

Nutrition

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NUTRIENTS

I. Water
 A. Water is the most important nutrient
 B. Requirement (mL/day) roughly equals 1.6 * resting energy requirement (RER) in dogs and 1.2 * RER in cats

II. Carbohydrates
 A. Includes sugars and starches
 B. Utilized as a source of glucose
 C. Carbohydrate ingredients include grains (e.g., wheat, corn, rice, barley, oats)
 D. Cooking increases the digestibility of carbohydrates

III. Fiber
 A. Resists enzymatic digestion; is fermented in the colon
 B. Fiber promotes and regulates normal bowel function
 C. Fiber sources differ in their fermentation properties
 D. The amount of fiber in the diet impacts the digestibility of the food

IV. Protein
 A. Proteins are composed of amino acids. Ten amino acids are essential in a dog diet, and 11 are essential in the cat
 B. Catabolism of protein produces waste nitrogen and generates ammonia, which can be toxic
 C. Protein is required in the diet because amino acids are continually being used in metabolic pathways
 D. Most commercial diets contain excess protein

V. Lipids
 A. Certain fatty acids (linoleic acid in the dog, linoleic and arachidonic acid in the cat) are required in the diet
 B. Fats are an important source of energy, providing more than twice the energy per gram compared with protein or carbohydrate
 C. Dietary fat improves the absorption of the fat soluble vitamins (A, D, E, and K)

VI. Minerals
 A. Required for many important functions in the body
 B. Minerals from meat sources are typically better utilized than minerals from plant sources
 C. A variety of medical problems can result from deficiency or excess of minerals
 1. Calcium
 a. Deficiency: Decreased bone mineralization, bone fractures
 b. Excess: Nephrosis, enlarged costochondral junctions
 2. Phosphorus
 a. Deficiency: Pica, rickets, poor growth
 b. Excess: Bone loss, calcification of soft tissues
 3. Potassium
 a. Deficiency: Anorexia, heart and kidney lesions
 b. Excess is rare
 4. Sodium, chloride
 a. Deficiency: Inability to maintain water balance
 b. Excess: Thirst, seizures, death
 5. Magnesium
 a. Deficiency: Muscular weakness, irritability, decreased bone density, seizures
 b. Excess: Uroliths, paralysis
 6. Iron
 a. Deficiency: Anemia, poor coat
 b. Excess: Anorexia, decreased liver function
 7. Zinc
 a. Deficiency: Alopecia, depigmentation of hair
 b. Excess: Rare
 8. Copper
 a. Deficiency: Depigmentation of hair, neuromuscular disorders
 b. Excess: Increased activity of liver enzymes
 9. Manganese
 a. Deficiency: Crooked legs, fatty liver
 b. Excess: Rare
 10. Iron
 a. Deficiency: Goiter, reproductive failure, myxedema
 b. Excess: Goiter, decreased appetite
 11. Selenium
 a. Deficiency: Muscular dystrophy, subcutaneous edema, renal mineralization
 b. Excess: Vomiting, staggering, salivation, nail loss
 12. Chromium
 a. Deficiency: Impaired glucose tolerance
 b. Excess: Dermatitis, lung cancer

VII. Vitamins
 A. Vitamins A, D, E, and K are fat-soluble vitamins. Intestinal absorption requires bile salts and

micelle formation; absorption is by passive transport. They are stored in fat; thus deficiency is less likely; however, they are more likely to cause toxicity

B. The remaining vitamins are water soluble and are absorbed by active transport. They can be depleted, rapidly causing deficiency; toxicity is uncommon

C. A variety of medical problems can result from deficiency or excess of minerals
 1. Vitamin A
 a. Deficiency: Anorexia, poor growth, weakness, fetal resorption
 b. Excess: Tooth loss, poor growth, cervical spondylosis
 2. Vitamin D
 a. Deficiency: Rickets, osteomalacia, bone fractures, enlarged costochondral junctions
 b. Excess: Hypercalcemia, calcinosis, anorexia, lameness
 3. Vitamin E
 a. Deficiency: Steatitis, dermatitis, anorexia, myopathy, immunodeficiency, sterility
 b. Excess: Minimal toxicity, impairment of absorption of other fat soluble vitamins, prolonged clotting times
 4. Vitamin K
 a. Deficiency: Prolonged clotting time, hemorrhage
 b. Excess: Minimal toxicity, anemia
 5. Thiamin (vitamin B_1)
 a. Deficiency: Anorexia, weight loss, ventriflexion in cats, paresis in dogs
 b. Excess: Hypotension, bradycardia
 6. Riboflavin (vitamin B_2)
 a. Deficiency: Ataxia, retarded growth, dermatitis, ocular discharge, bradycardia, fatty liver in cats
 b. Excess: Minimal toxicity
 7. Niacin (vitamin B_3)
 a. Deficiency: Anorexia, diarrhea, poor growth, ulceration of mucosa and necrosis of tongue, drooling
 b. Excess: Melena, convulsions
 8. Pyridoxine (vitamin B_6)
 a. Deficiency: Anorexia, weight loss, poor growth, microcytic hypochromic anemia
 b. Excess: Anorexia, ataxia
 9. Pantothenic acid
 a. Deficiency: Fatty liver, emaciation, poor growth, tachycardia, coma
 b. Excess: No toxicity
 10. Folic acid
 a. Deficiency: Anorexia, weight loss, glossitis, leucopenia, megaloblastic anemia in cats, hypochromic anemia
 b. Excess: No toxicity
 11. Biotin
 a. Deficiency: Hyperkeratosis; alopecia; crusty secretions around eyes, nose, and mouth; drooling; diarrhea
 b. Excess: No toxicity
 12. Cobalamin (vitamin B_{12})
 a. Deficiency: Poor growth, anemia
 b. Excess: Altered reflexes
 13. Vitamin C: No signs of deficiency or toxicity in dogs or cats
 14. Choline
 a. Deficiency: Thymic atrophy, poor growth, anorexia, fatty liver
 b. Excess: No toxicity
 15. Carnitine
 a. Deficiency: Cardiomyopathy, hyperlipidemia
 b. Excess: No toxicity

ENERGY REQUIREMENTS

I. Dogs
 A. Resting energy requirement (RER)
 1. RER (kcal) = 70*(body weight [BW] [kg])$^{0.75}$
 2. If BW is between 2 and 45 kg, RER (kcal) is approx 30*(BW [kg]) + 70
 B. Maintenance energy requirement (MER) depends on physiologic state and ranges from 1.0 * RER in obese individuals to 1.8 * RER in intact adults
 C. Work energy requirement ranges from 2 * RER for light work to 8 * RER for heavy work
 D. Gestation
 1. First 42 days, feed as an intact adult (1.8 * RER)
 2. Last 21 days, feed 3* RER (or more if needed)
 E. Lactation energy requirement ranges from 4 to 8 * RER, depending on the number of puppies nursing
 F. Growth energy requirement
 1. First 4 months of life= about 3 * RER
 2. After 4 months = about 2 * RER until adult size is reached

II. Cats
 A. RER is calculated as for dogs
 B. MER ranges from 0.8 * RER in obese individuals to 1.6 * RER in active intact adults
 C. Gestation
 1. Energy requirements increase linearly during gestation
 2. Feed at 1.6 * RER at breeding and gradually increase to 2 * RER by parturition
 3. Free-choice feeding is recommended
 D. Lactation energy requirement ranges from 2 to 6 * RER, depending on the number of kittens nursing
 E. Growth energy requirement is about 2.5 * RER until adult size is reached

PET FOODS

I. Federal and state agencies regulate pet food labels and ingredients. The Association of American Feed Control Officials (AAFCO) has regulations regarding the ingredients that can be included in commercial pet foods. They also regulate what may be stated on the pet food label

II. Pet food labels
 A. The display panel must include the manufacturer's name, the name of the product, net weight, which stage of life the food is designed for, a description of the product, and the nutrition claim

B. The information panel must include a list of ingredients, the guaranteed analysis, a nutritional adequacy statement, feeding guidelines, and manufacturer or distributor
 1. Ingredients must be listed in descending order by weight in the formula. Ingredient names must conform to AAFCO guidelines. The ingredient list gives information regarding relative amounts, but it does not provide any information as to the quality or digestibility of the ingredients. Also realize that wet ingredients will be at the beginning of the ingredient listing because water in the wet ingredient contributes to the weight, making it heavier
 2. The guaranteed analysis panel must include the minimum percentages for protein and fat and maximum percentages for crude fiber and moisture. These percentages are the percentages "as-fed." They do not give any indication as to the caloric density or digestibility of the product
 3. The nutritional adequacy statement tells whether the product is designed for adult maintenance or growth and reproduction. There are two methods for determining nutritional adequacy:
 a. Formulation method: With this method, the manufacturer guarantees that the formulation on paper meets the nutritional needs either for adult maintenance or for growth and reproduction
 b. Feeding trial method: With this method, the manufacturer has conducted feeding trials to guarantee that the product actually meets the nutritional needs for maintenance or growth and reproduction. This method is preferred to the formulation method, but it is more expensive

III. Calorie content
 A. The kcal/g of diet (metabolizable energy [ME]) is typically not provided on the pet food label but may be obtained either from product literature or directly from the manufacturer
 B. Two diets can appear very similar in percentages of protein and fat but can be quite different in terms of ME. Diets should not be compared on the basis of percentages, but they should be compared using ME. ME takes into account the caloric density and digestibility of the diet

IV. Homemade diets
 A. Recipes should be chosen from reputable sources or formulated by a veterinary nutritionist who offers this service
 B. All foods should be cooked to destroy any bacteria present in raw products. Cooking also improves the digestibility of the starch in the diet
 C. Recipes need to be strictly followed with minimal substitution to ensure that the diet is nutritionally adequate. A gram scale for weighing ingredients is recommended
 D. Periodically a sample of the diet should be submitted to a laboratory for analysis to ensure nutritional content
 E. Vegetarian diets can be developed for dogs but are difficult to develop for cats because of their unique nutritional requirements
 F. Vitamin and mineral supplements should be added to the diet, but only after the other ingredients have been cooked
 G. Small batches of food should be made because these diets do not contain preservatives. Food should be kept in the refrigerator between feedings, and larger batches can be frozen
 H. Patients consuming homemade diets should be evaluated by a veterinarian at least 2 to 3 times per year. Special attention should be paid to the skin and hair. Calcium and vitamin D status should be monitored, as nutritional secondary hyperparathyroidism is not uncommon in animals receiving a diet deficient in calcium or vitamin D or excessive in phosphorus

NUTRITION UNIQUE TO THE CAT

I. Cats are strict carnivores; dogs are omnivores

II. Nutrient requirements
 A. Energy metabolism: Cats have a low liver glucokinase activity and thus cannot metabolize a large amount of simple carbohydrate
 B. Protein metabolism
 1. Cats have a much higher protein requirement than do dogs because of the high activity rate of liver transaminases and deaminases. Dogs (omnivores) and herbivores can decrease this enzyme activity when low-protein diets are fed, but cats cannot
 2. Arginine is required in the cat for conversion of ammonia to urea. Arginine-deficient diets rapidly result in ammonia toxicity
 3. Taurine is required in the cat
 a. Cats have a low rate of taurine synthesis; and, unlike other species, cats can utilize taurine only for conjugation with bile acids. Thus taurine is lost at a high rate
 b. Deficiency of taurine leads to central retinal degeneration, reproductive failure, and the development of dilated cardiomyopathy
 c. Taurine is abundant in animal tissues but absent in plants
 4. Methionine and cystine
 a. Sulfur-containing amino acids required in high levels by the cat
 b. Signs of deficiency include poor growth and crusting dermatitis at mucocutaneous junctions
 c. About 20% of a cat's diet should be animal protein to supply adequate methionine
 C. Lipid metabolism
 1. In addition to linoleic and linolenic acid, the cat also requires arachidonic acid in the diet. The cat cannot synthesize arachidonic acid from linoleic acid (as can the dog)
 2. Arachidonic acid is found in animal tissues, but not in plants
 D. Vitamins
 1. Niacin is required by the cat in higher amounts than in the dog because cats do not have sufficient

conversion of tryptophan to niacin. Niacin is found in high quantities in animal tissue
2. Pyridoxine is required in higher quantity in the cat compared with the dog because of the high transaminase activity
3. Vitamin A is required by the cat because cats cannot convert vitamin A precursors (β-carotene) to vitamin A, as can the dog. Vitamin A occurs naturally only in animal tissues

E. Water: Cats do not have a strong thirst stimulus, and thus they are able to form highly concentrated urine

III. Feeding practices
A. Cats typically eat 10 to 20 small meals per day
B. Cats may be more difficult to transition to a new diet. Transitioning should be done slowly for best success
C. Cats develop food aversions easily, especially if the food is associated with GI upset. This can be important if introducing a prescription diet while a cat is hospitalized
D. Most cats prefer solid, moist foods that resemble flesh and prefer foods close to body temperature

DIETARY MANAGEMENT IN DISEASES

I. Obesity
A. Decrease the caloric density of the food
B. Increased dietary fiber can dilute the caloric content of the food and provides bulk
C. Feed low to moderate dietary fat
D. Maintain adequate dietary protein to prevent lean body mass

II. Diabetes mellitus
A. The water requirement is increased in diabetes, so make sure adequate water is provided
B. Avoid simple sugars, and provide complex carbohydrates
C. Feed a diet moderate in fiber
D. Feed a moderate quantity of protein; protein should be highly digestible
E. Semi-moist foods have a hyperglycemic effect and should be avoided
F. Electrolytes may become depleted because of increased urinary losses
G. Chromium supplementation may improve glucose tolerance
H. Many cats with diabetes are obese and should be moderately calorie-restricted to cause weight loss but prevent the development of hepatic lipidosis

III. Chronic renal failure
A. Make sure adequate water is available at all times
B. Avoid excess protein intake, but make sure that adequate protein is provided. In later-stage renal disease, protein may need to be further restricted
C. Restrict dietary phosphorus
D. Avoid excess dietary sodium
E. Ensure adequate caloric intake
F. If hypokalemia occurs, provide potassium supplementation (especially in cats)
G. ω-3 fatty acid supplementation may be beneficial
H. Calcitriol levels decrease in renal failure and may need to be supplemented to prevent secondary hyperparathyroidism

IV. Urolithiasis: Canine
A. Calcium oxalate uroliths (prevention)
1. Encourage water intake
2. Avoid excess dietary protein
3. Avoid excess dietary calcium and sodium
4. Avoid both an excess or deficiency of magnesium
5. Avoid foods high in oxalates (asparagus, spinach, broccoli, peanuts, soybeans, sardines, green beans, corn, apples)
6. Avoid excess vitamin D
7. Maintain urinary pH between 6.8 and 7.2

B. Calcium phosphate uroliths (prevention)
1. Encourage water intake
2. Avoid excess dietary protein
3. Avoid excess dietary phosphorus, sodium, calcium, and vitamin D

C. Struvite uroliths
1. Encourage water intake
2. Maintain an acidic urine
a. For prevention, maintain pH between 6.2 and 6.4
b. For dissolution, maintain pH between 5.9 and 6.1
3. Restrict protein intake. Feed lower protein intake for dissolution as opposed to prevention
4. Restrict phosphorus and magnesium intake

D. Ammonium urate uroliths
1. Encourage water intake
2. Avoid excess dietary protein
3. Maintain an alkaline urine pH (pH 7.0 to 7.5)

E. Cystine uroliths
1. Encourage water intake
2. Avoid excess dietary protein
3. Maintain an alkaline urinary pH (pH 7.1 to 7.7)

V. Urolithiasis: Feline
A. Struvite uroliths
1. Encourage water intake
2. Avoid excess dietary protein
3. Avoid excess dietary phosphorus and magnesium
4. Avoid obesity, but an increased energy density can decrease mineral intake
5. Maintain an acidic urine

B. Calcium oxalate uroliths
1. Encourage water intake
2. Avoid excess dietary protein
3. Avoid obesity, but an increased energy density can decrease mineral intake
4. Avoid excess calcium
5. Avoid either an excess or deficiency of magnesium
6. Maintain a slightly acidic urine (pH 6.6 to 6.8)

VI. Adverse reactions to foods
A. Use a novel protein source, or limit dietary protein to one or two protein sources
B. Avoid excess levels of dietary protein. Protein should be highly digestible
C. In dogs with diarrhea, avoid foods containing wheat, barley, or rye
D. Avoid foods that contain tuna or mackerel
E. Feed a food that has reduced or no food additives

VII. Congestive heart failure
A. Avoid excess sodium intake

1. Prescription diets formulated for cardiac disease have the lowest concentration of sodium
2. Many geriatric foods and renal diets also contain lower amounts of sodium compared with regular adult diets

B. Potassium, magnesium, and phosphorus
1. Electrolyte abnormalities may occur as a result of the administration of cardiac drugs
 a. Diuretics may cause a loss of potassium and magnesium
 b. Angiotensin-converting enzyme inhibitors may cause hyperkalemia
2. Restrict phosphorus if chronic renal failure is also present

C. Taurine
1. Taurine supplementation may be beneficial, especially if there has been a taurine deficiency
2. In dogs, taurine deficiency in association with cardiomyopathy has been shown in cocker spaniels and golden retrievers
3. Some cardiac diets include high levels of taurine, and supplemental taurine is not necessary if one of these diets is being consumed

D. Carnitine
1. Carnitine supplementation will be most beneficial in those with carnitine deficiency
2. Significant improvement is usually seen on the echocardiogram within 8 to 12 weeks of supplementation

E. Fish oil
1. Fish oil is high in ω-3 fatty acids
2. Fish oil may decrease tumor necrosis factor and interleukin-1 concentrations that are associated with cachexia

VIII. Hepatic disease

A. Copper-associated hepatotoxicosis
1. Maintain adult protein requirements unless there are signs of hepatic encephalopathy
2. Restrict copper intake. Diets should not contain more than 5 ppm copper on a dry matter basis
3. Zinc supplementation can be used partially to block copper absorption
4. Antioxidant vitamins such as vitamin E and vitamin C may be beneficial to prevent lipid peroxidation that occurs in copper-associated hepatotoxicosis

B. Portosystemic shunt
1. Protein
 a. Should be from a highly digestible source
 b. Protein content may need to be moderately restricted if signs of hepatic encephalopathy are present
2. Fat is an important source of calories in animals with portosystemic shunt

C. Chronic hepatitis or cirrhosis
1. Protein
 a. Hypoalbuminemia is an important problem with hepatitis, and protein intake should be maintained at normal adult levels
 b. If signs of hepatic encephalopathy are present, protein should be restricted
2. Adequate caloric intake is important to prevent tissue catabolism
3. Antioxidant vitamins such as vitamins E and C may have benefit to prevent lipid peroxidation

D. Feline hepatic lipidosis
1. Provision of adequate calories is most important. Many cats are fed via feeding tube
2. Protein deficiency may play a role in the pathogenesis of hepatic lipidosis. Moderate amounts of protein should be fed and should contain adequate taurine and arginine
3. Potassium supplementation should be considered because many cats with hepatic lipidosis are hypokalemic
4. Carnitine supplementation is beneficial in obese cats undergoing weight loss. It may also have some benefit in those with hepatic lipidosis

E. Portal hypertension
1. Sodium chloride should be restricted in those with ascites or hypoproteinemia
2. Adequate calorie intake needs to be maintained

F. Other nutritional factors
1. An increase in dietary fiber may be beneficial by reducing the production of nitrogenous waste in the gastrointestinal (GI) tract
2. Iron supplementation may help in those with GI ulceration or hemorrhage associated with liver disease
3. Vitamin K may become deficient in those with chronic liver disease, leading to altered coagulation. Vitamin K supplementation is helpful in those patients

IX. Primary lipid disorders

A. Animals with a primary lipid disorder should be placed on a low fat diet. Fat intake should be determined on a g/kcal basis, not just on the percentage of fat in the diet

B. The addition of ω-3 fatty acids in the form of fish oil supplementation can be very effective at lowering triglyceride concentrations

X. GI disorders

A. Pharyngeal and esophageal disorders
1. A high dietary fat content can help maintain adequate calories. A lower fat content is a better option if there is esophageal reflux
2. Dietary protein content should be greater than 25% dry matter
3. A gruel consistency is best if there is esophageal obstruction or esophagitis. Dry food or a bolus of moist food is better if there is megaesophagus
4. Feeding small amounts of food in an upright position is recommended

B. Hairballs
1. Larger kibble size increases the passage of hairballs out of the stomach and decreases vomiting
2. An increase in dietary fiber can help prevent hairballs

C. Gastritis
1. Feed only one or two novel protein sources, and keep protein to a minimum
2. Do not feed high-fat diets as these delay gastric emptying

3. Maintain adequate potassium in those that are vomiting
4. Iron, copper, and B vitamin supplementation may be helpful in those with GI blood loss

D. Prevention of gastric dilatation or volvulus
1. Feed multiple small meals per day rather than one large meal
2. Increase the amount of time to consume a meal to prevent ingestion of air. Feed from a very small container, feed a large kibble-sized food, or add obstacles to the food bowl
3. Feed a mixture of dry and moist food

E. Acute enteritis
1. Withhold oral intake of food and water for the first 24 to 48 hours
2. Preventing dehydration is most important. Provide adequate fluids either orally or parenterally
3. Electrolyte disorders are common; monitor potassium, sodium, and chloride especially
4. Feed a moderate fat level
5. Feed a diet that is highly digestible
6. Either feed a diet low in fiber, or feed a moderate mixture of soluble and insoluble fiber
7. Glutamine supplementation is beneficial

F. Inflammatory bowel disease (IBD)
1. Limit dietary protein to one or two sources.
2. The diet should be a highly digestible protein source
3. Hypokalemia and dehydration are common, so make sure there is adequate water and potassium consumption
4. Feed a moderate fat content. High-fat foods contribute to diarrhea
5. Fiber should be fed at a moderate level. Fiber sources such as beet pulp, fructooligosaccharides or inulin produce volatile fatty acids that may be beneficial
6. Zinc deficiency can occur in IBD, so assess zinc consumption
7. Omega-3 fatty acid supplementation may have benefit
8. Feed multiple small meals per day

G. Lymphangiectasia or protein-losing enteropathy
1. Feed a diet high in dietary protein. The protein source should be highly digestible
2. Feed a diet relatively low in fat
3. Medium-chain triglyceride (MCT) supplement may be beneficial in providing calories. MCT oil is not very palatable, however
4. Feed a diet low in fiber
5. Fat-soluble vitamin supplementation may be needed
6. Feed multiple small meals per day

H. Small intestinal bacterial overgrowth
1. Feed a highly digestible diet with a highly digestible protein source
2. Feed a moderate fat diet. High-fat foods contribute to diarrhea
3. Fructooligosaccharides can reduce the bacterial load

I. Colitis
1. Correct dehydration and electrolyte abnormalities
2. Feed a highly digestible diet, with a highly digestible protein source
3. Restrict protein to one or two sources
4. Moderate-fat diets are best, though some can tolerate higher fat diets if calories are needed
5. Folic acid supplementation may be beneficial
6. ω-3 fatty acid supplementation may also be of benefit
7. Either low dietary fiber or a moderate amount of mixed soluble-insoluble fiber is recommended. Beet pulp, fructooligosaccharides, or inulin may be beneficial fiber sources
8. If colitis is acute, withhold food for 24 to 48 hours

J. IBS: Feed a diet with an increased level of insoluble fiber

K. Constipation
1. Encourage water intake
2. Feed a diet with an increased level of insoluble fiber

XI. Pancreatic disorders

A. Exocrine pancreatic insufficiency
1. Feed a highly digestible food with added pancreatic enzymes
2. The diet should be very low in fiber
3. Fat content should be low to moderate. MCT oil may be added if additional calories are needed
4. Fat-soluble vitamin supplementation should be considered

B. Pancreatitis
1. Discontinue oral intake of food and water until vomiting stops. Provide parenteral nutrition if necessary
2. Avoid excess dietary protein because free amino acids can stimulate pancreatic secretion. Maintain adequate protein ingestion
3. Ensure adequate water intake
4. Feed a diet low to moderate in fat

XII. Cancer

A. Cancer cachexia is an important issue. In addition, chemotherapy and radiation therapy may impact the ability to consume food. Nutritional support may need to be provided early during the course of therapy to prevent weight loss

B. Carbohydrate metabolism may be altered in some cancers, and carbohydrates might not be utilized as efficiently as a result of insulin resistance. Carbohydrates should supply only about 10% of the daily energy requirement

C. Many cancer patients have decreased muscle mass and decreased protein synthesis. Protein should exceed levels normally needed for maintenance. Additional arginine may decrease tumor growth and metastatic rate. Additional glutamine may also be beneficial where there is intestinal injury

D. A large proportion of daily calories should come from fat. ω-3 fatty acids may inhibit tumorigenesis and metastasis, and additional ω-3 fatty acids (such as from fish oil) may be beneficial

E. Vitamins A, E, and C have been shown in some studies to be beneficial during cancer therapy

F. Zinc or selenium deficiency has been associated with increased incidence of cancer. Low levels of iron may be beneficial to slow tumor growth

XIII. Skin and hair disorders
- A. Avoid protein and energy deficiency. Feed a moderately to highly digestible diet
- B. Avoid fatty acid deficiency. Dogs and cats require linoleic acid, and cats additionally require arachidonic acid
- C. Provide adequate dietary zinc, copper, and iron
- D. Some skin diseases are responsive to vitamin A supplementation, but excesses can be toxic
- E. Some diseases (such as lupus) may respond to vitamin E supplementation

Supplemental Reading

Hand MS, Thatcher CD, Remillard RL, Roudebush P, eds. *Small Animal Clinical Nutrition*, 4th ed. Topeka, KS, 2000, Mark Morris Institute.

Pibot P, Biourge V, Elliott D, eds. *Encyclopedia of Canine Clinical Nutrition*. Aimargues, France, 2006, Royal Canin.

Pibot P, Biourge V, Elliott D, eds. *Encyclopedia of Feline Clinical Nutrition*. Aimargues, France, 2009, Royal Canin.

Case LP, Carey DP, Hirakawa DA, Daristotle L, eds. *Canine and Feline Nutrition: A Resource for Companion Animal Professionals*, 2nd ed. St Louis, 2000, Mosby.

21 CHAPTER

Oncology

Patricia A. Schenck

ONCOLOGY PRINCIPLES

I. Presentation
 A. Pay particular attention to the age, sex, breed, and species, as this information often helps with the diagnosis
 B. The location of the tumor, the duration, and growth rate are also important
 C. A complete physical examination is necessary to assess the overall health of the animal. Regional lymph nodes should be carefully palpated and the lungs assessed

II. Diagnosis
 A. Laboratory evaluation
 1. A complete blood cell count (CBC), serum biochemistry profile, and urinalysis should be performed to assess overall health
 2. Other laboratory tests are performed as needed (e.g., feline leukemia virus [FeLV], bone marrow aspirate, adrenal function tests)
 B. Diagnostic imaging
 1. Radiographs (thorax, abdomen, skeleton) should be taken to determine the presence of metastases
 2. Ultrasound is most useful to visualize the abdomen
 C. Cytology
 1. Can provide rapid and inexpensive diagnostic information
 2. Do not overinterpret cytology preparations
 3. Definitive diagnosis most often requires histopathology
 D. Biopsy
 1. Larger samples provide a more accurate diagnosis
 2. Fix tissue samples in 10% buffered formalin
 3. Histologic samples should contain the neoplastic tissue with a margin of normal tissue

III. Principles of therapy
 A. Surgery
 1. Most useful for localized tumors
 2. Resect all neoplastic tissue, if possible with wide margins
 3. Prevent surgical spread of cancer cells
 a. Minimize the manipulation of the tumor
 b. Protect healthy tissues from tumor cell contamination with the use of barrier drapes
 c. Change gloves, drapes, and instruments during surgery if necessary
 B. Radiotherapy
 1. Used for local or regional tumors
 2. Can be used before surgery to reduce the size of the tumor, concurrently with chemotherapy, or postoperatively
 3. The effectiveness of radiation therapy can be improved by chemotherapy-induced radiosensitization
 4. Need to irradiate potentially affected tissues and a normal tissue margin
 5. Frequent small doses of radiation allow for repair of normal cells and decreased radiation toxicity
 6. Radiation is most effective when the tumor size is small
 C. Chemotherapy
 1. Most often used for regional or disseminated neoplasms
 2. Some tumors are quite chemosensitive (lymphoid neoplasia)
 3. Administer chemotherapy agents at the maximal tolerated dose
 4. Continue chemotherapy after apparent remission because a microscopic tumor remains after the tumor can no longer be physically detected
 5. Tumors can become drug resistant; the larger the tumor, the more likely that it will become resistant
 6. Patients should be reevaluated at regular intervals post therapy
 D. Nutritional management
 1. Anorexia is common (cancer cachexia) and may be related to the side effects of therapy or to tumor-produced anorexigenic substances
 2. Provide enteral or parenteral feeding if patients do not eat for more than 5 days or have an acute loss of 10% or more of body weight
 3. Malnourished patients show hypoalbuminemia, lymphopenia, and anemia
 4. Malnutrition adversely impacts the immune system, delays wound healing and cell repair, and increases morbidity and mortality
 E. Pain management
 1. Acute vs. chronic; treatment vs. tumor-related
 2. Contributes to anorexia, weight loss, reduced mobility, depression
 3. Prevention or early treatment of pain is more effective than treating severe or chronic pain
 4. Provide pain relief with minimal sedation and other side effects

LYMPHOID NEOPLASIA

I. Lymphoma
 A. Cause
 1. Retrovirus can cause lymphoma in the cat, chicken, and human
 2. In the cat, both FeLV and feline immunodeficiency virus (FIV) can cause lymphoma
 3. In the dog, a viral etiology has not been established
 4. Genetics may play a role; exposure to environmental carcinogens may also play a role in development
 B. Classification and clinical signs (Tables 21-1 and 21-2)
 1. Multicentric lymphoma is the most common form in the dog. Enlarged lymph nodes are typically palpated. Other clinical signs include weight loss, decreased appetite, polyuria (PU)/polydipsia (PD), and lethargy. Enlargement of the liver and spleen are commonly seen
 2. Alimentary lymphoma is associated with gastrointestinal (GI) signs such as vomiting, diarrhea, weight loss, and lethargy
 3. Mediastinal lymphoma usually causes respiratory signs. Most mediastinal lymphomas are associated with hypercalcemia
 4. Cutaneous lymphoma varies in appearance. Many are pruritic
 5. Extranodal lymphoma includes lymphoma in the eye, central nervous system (CNS), bones, heart, kidneys, urinary bladder, and nasal cavity
 6. B-cell vs. T-cell lymphoma
 a. In the dog, most are B-cell lymphomas. T-cell lymphoma is associated with hypercalcemia, and cranial mediastinal tumors
 b. Most FeLV associated lymphomas in cats are T-cell lymphomas
 7. Most animals are middle-aged or older
 C. Diagnosis
 1. Physical examination
 a. Palpate all lymph nodes
 b. Evaluate organ involvement, especially liver or kidney involvement
 c. Bone marrow involvement can cause hematologic abnormalities
 d. Ophthalmic problems such as uveitis, hemorrhage, and ocular infiltration occur in about 33% of dogs with lymphoma
 2. Laboratory evaluation
 a. Immature lymphocytes are usually seen in the circulation
 b. Normocytic, normochromic, nonregenerative anemia is common
 c. Bone marrow aspirate may show neoplastic lymphocytes
 d. Hypercalcemia is seen in about 20% of those with lymphoma
 e. Increased blood urea nitrogen and creatinine may be seen with kidney involvement
 f. If there is liver involvement, liver enzymes may be increased
 g. Most cats with mediastinal or multicentric lymphoma are FeLV positive

Table 21-1 World Health Organization Clinical Staging for Domestic Animals with Lymphoma

Stage	Criteria
I	Single lymph node
II	Multiple lymph nodes in a regional area
III	Generalized lymphadenopathy
IV	Liver or spleen involvement (with or without stage III)
V	Bone marrow or blood involvement or any nonlymphoid organ (with or without stages I to IV)
Substage a	Without clinical signs of disease
Substage b	With clinical signs of disease

World Health Organization (WHO). *TNM Classification of Tumors in Domestic Animals.* Geneva, 1980, WHO.

Table 21-2 Characteristics of Feline Lymphoma by Anatomic Site

Anatomic Site	Relative Frequency	Age	T-Cell Association	FeLV Positive
Alimentary	50%-70%	~10-14 yr	High	Low (5%)
Multicentric	10%-25%	Depends on feline leukemia virus (FeLV) status*	Depends on FeLV status*	Approximately one third
Mediastinal/thymic	10%-20%	Young	High	High (>80%)
Nasal	~10%	Aged	Low	Low
Renal	5%-10%	Middle-aged	Low to moderate	Low to moderate
Other	5%-25%	Mixed	Mixed	Mixed

*FeLV-positive cats tend to be younger, and the cancer is more commonly of T-cell derivation.
From Ettinger SJ, Feldman EC, editors. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.

3. Diagnostic imaging
 a. Radiography/ultrasound can be helpful to evaluate organ involvement
 b. Thoracic radiographs should be taken in any case of hypercalcemia of unknown origin
 c. Enlarged sternal and sublumbar lymph nodes occur in about half of lymphomas
4. Histopathology of lymph nodes is recommended. With cytology, neoplasia can be difficult to distinguish from benign lymphadenopathy
5. Other tests
 a. May need to do an exploratory laparotomy
 b. Cerebrospinal fluid cytological evaluation may help in the diagnosis of CNS lymphoma in the dog
6. Differential diagnosis
 a. Lymphadenopathy differentials include infectious diseases, immune-mediated diseases, and other metastatic neoplasia
 b. Differentials for alimentary lymphoma include lymphocytic enteritis, other intestinal neoplasias, granulomatous disease, and hypereosinophilic syndrome
 c. Differentials for mediastinal lymphoma include thyroid tumors, heart base tumors, thymoma, and pulmonary granulomatosis
 d. Differentials for cutaneous lymphoma include pyoderma, immune-mediated disorders, parasitic skin disorders, and other cutaneous neoplasia

D. Treatment
1. Require chemotherapy. Without treatment, most live only 4 to 6 weeks after diagnosis
2. With chemotherapy, up to 90% of dogs and 70% of cats enter remission and survive up to a median of one year. Cures are uncommon, but about 25% can live 2 or more years. If cats can achieve remission, they can survive for long periods
3. Cats have fewer adverse effects unless they are treated with doxorubicin. Do not give doxorubicin to cats with renal disease
4. Combination protocols tend to be more effective, with longer remissions and survival time; they are also more costly and more time-consuming
5. Protocols: A number of protocols are available. The most common protocols are discussed below:
 a. The CHOP combination protocol (C = cyclophosphamide, H = hydroxydaunorubicin [doxorubicin], O = Oncovin [Vincristine], P = prednisone) (University of Wisconsin-Madison Short Protocol). Patients are off all medication after 19 weeks. L-asparaginase is no longer a part of this protocol; L-asparaginase is reserved for "rescue"
 b. Doxorubicin used alone achieves remission in about 70% of dogs
 c. Prednisone used alone is inexpensive, but the survival time is only about 2 months
6. If cytopenia is present, prednisone, L-asparaginase, and vincristine are used, as these agents tend to spare the bone marrow. However, if cytopenia is the result of bone marrow infiltration, aggressive chemotherapy is required
7. Reinduction and Rescue therapy
 a. If a patient that has previously been in remission has a recurrence of lymphoma, the same protocol that was used initially should be reintroduced. After reinduction, the length of remission is typically half that initially used
 b. Rescue therapy is instituted when remission cannot be obtained with the regular protocol. Drugs used for rescue include mitoxantrone, L-asparaginase, lomustine, and actinomycin-D. Remissions achieved with a rescue protocol are generally short
8. Small cell lymphomas tend to be more resistant to therapy. Chlorambucil and prednisone therapy appear helpful
9. Surgery combined with radiation therapy and chemotherapy may be beneficial in CNS lymphoma
10. Cutaneous lymphoma is resistant to chemotherapy and may be able to be treated with surgery and radiotherapy. Lomustine, retinoic acid, or L-asparaginase may be beneficial

E. Prognosis
1. Dogs
 a. Stage V, or substage b, are associated with shorter remission and survival times
 b. T-cell lymphoma has a shorter remission and survival time
 c. Female dogs may have a longer survival time
 d. Hypercalcemia is associated with T-cell lymphoma and a worse prognosis
 e. GI lymphoma, disseminated cutaneous, or leukemic forms have a poorer prognosis
2. Cats
 a. The higher the clinical stage, the poorer the prognosis
 b. FeLV positive cats have a poorer prognosis
 c. The presence of leukemia, anemia, neutropenia, and sepsis worsen the prognosis
 d. Cats that achieve remission early have a better prognosis

II. Lymphoid leukemia

A. Acute lymphoblastic leukemia (ALL)
1. Clinical signs
 a. Signs include fever, abdominal pain, anorexia, splenomegaly, and pale mucous membranes
 b. Dogs are usually late middle-aged; affected cats are younger
 c. Anemia occurs in most patients; 25% are thrombocytopenic
 d. Almost all cats with ALL also have FeLV
2. Diagnosis
 a. Documentation of abnormal lymphocytes in bone marrow or blood

b. Most have leukocytosis; about 10% have aleukemic leukemia (bone marrow involvement with no peripheral blood involvement). Special stains may be needed
c. Differentiate from lymphoma. ALL has a more acute progression and less likelihood of lymphadenopathy; patients have a poor response to therapy and shorter survival times

3. Treatment
a. CHOP-based protocol
b. Poor prognosis

B. Chronic lymphocytic leukemia (CLL)
1. Clinical signs
a. Most dogs have lymphadenopathy and splenomegaly, pale mucous membranes, and fever
b. Clinical signs are usually nonspecific (lethargy, PU, PD, intermittent lameness, episodes of collapse, bleeding gums, epistaxis)

2. Clinical pathology
a. Most have normocytic, normochromic, nonregenerative anemia, thrombocytopenia
b. About one third have hyperproteinemia with monoclonal gammopathies
c. Cats are FeLV negative

3. Treatment
a. Treatment is recommended only in symptomatic patients
b. In dogs, prednisone and chlorambucil are most commonly used
c. The prognosis for CLL is better than that for ALL

III. Plasma cell neoplasia
A. Multiple myeloma
1. Clinical signs
a. Occurs in older dogs; no sex predilection
b. Nonspecific clinical signs (anorexia, listless, PU, PD)
c. Most have lameness secondary to bone pain
d. Epistaxis and gingival bleeding due to hyperviscosity syndrome occurs in about 50% of cases

2. Diagnosis
a. About 75% of dogs have a monoclonal gammopathy, usually immunoglobulin G or immunoglobulin A
b. Bence Jones proteins may be present in the urine (cannot be detected by urine dipstick)
c. May have a nonregenerative, normocytic, normochromic anemia. Thrombocytopenia occurs in about 30%; 10% have circulating abnormal plasmacytes
d. About 20% have hypercalcemia secondary to bone resorption
e. For diagnosis, three abnormalities should be present: Bone marrow plasmacytosis, osteolytic bone lesions, and serum or urine myeloma proteins

3. Differential diagnosis
a. Ehrlichiosis can also cause a monoclonal gammopathy
b. Other differentials include carcinomas, connective tissue disorders, liver disease, hypersensitivity, and infections

4. Treatment
a. In the dog, the short-term prognosis is good; in the cat the prognosis is poor
b. Chemotherapy includes melphalan and prednisone. Remission occurs in about 90% of cases
c. Once remission is lost, a combination of doxorubicin, vincristine, and dexamethasone may be helpful

B. Plasmacytoma
1. Solitary plasmacytoma
a. Rare; tends to progress to multiple myeloma
b. Can treat with surgery or radiation therapy; use melphalan and prednisone if there is systemic involvement

2. Extramedullary plasmacytoma
a. Oral or cutaneous extramedullary plasmacytomas are usually benign
b. GI extramedullary plasmacytoma behaves like a malignancy. If it is localized, excision can be attempted

SARCOMAS AND MAST CELL TUMORS

I. Soft tissue sarcomas
A. Cause
1. Unknown
2. Genetics may play a role since some breeds (boxers, German shepherd dogs, Great Danes, Saint Bernards, golden retrievers, basset hounds, flat-coated retrievers) are at increased risk
3. Viral agents may play a role in cats, rodents, poultry, and nonhuman primates
4. Chemical carcinogens, ionizing radiation, chronic tissue inflammation, trauma, and vaccinations are also potential causes

B. Biologic behavior
1. Usually invasive and infiltrative with poorly defined margins
2. Metastasis depends on the grade of the tumor

C. Types
1. Liposarcoma
a. Originate from adipocytes
b. Rare; invasive and aggressive
c. Metastasis is uncommon

2. Hemangiopericytoma
a. Originates from the pericytes, which surround arterioles
b. German shepherd dogs have an increased risk
c. Infiltrative; recurrence is common
d. Rarely metastasize
e. Usually on extremities

3. Fibrosarcoma
a. Common
b. Invasive but slow growing
c. Usually do not metastasize (except for injection-site sarcomas)

4. Hemangiosarcoma
 a. Originates from endothelium of blood vessels
 b. Rapid growing; invasive
 c. German shepherd dogs at increased risk; rare in cats
 d. Usually in spleen, heart, and skin; metastasis is common
 e. May cause collapse if the tumor ruptures with hemorrhage
5. Neurofibrosarcoma
 a. Originates from nerve sheaths
 b. Slow growing, but invasive; metastasis is rare
 c. Commonly in the brachial or lumbosacral plexus; may see progressive lameness
6. Myxosarcoma
 a. Rare
 b. Infiltrative, but metastasis is uncommon
7. Rhabdomyosarcoma
 a. Originate in striated muscle
 b. Infiltrative; metastasis can occur
 c. Usually in heart, urinary bladder, and appendicular muscle
8. Leiomyosarcoma
 a. Originates in smooth muscle
 b. Rare; infiltrative but slow growing
 c. Common sites are spleen, liver, GI tract, and urinary tract; metastasis is possible
 d. May cause hypoglycemia
9. Synovial cell sarcoma
 a. Originates in the periarticular mesenchymal tissue
 b. Aggressive; metastasis occurs
 c. Large-breed dogs at increased risk
10. Lymphangiosarcoma
 a. Originates in the lymphatic endothelial vessels
 b. Rare; invasive but metastasis is rare
 c. May see edema or draining tracts on the skin
11. Malignant fibrous histiocytoma
 a. Contains a mixture of fibroblast and histiocytic cells
 b. Usually subcutaneous
 c. Invasive, but metastasis is uncommon. May cause bone lysis
12. Injection-site sarcomas (feline)
 a. Usually fibrosarcomas but may be a rhabdomyosarcoma, leiomyosarcoma, chondrosarcoma, osteosarcoma (OSA), malignant fibrous histiocytoma, or undifferentiated sarcoma
 b. The number of giant cells present correlates with the grade
 c. Invasive and aggressive; metastasis occurs

D. Clinical signs
 1. Depends on location, size, invasiveness, and presence of metastases
 2. More common in older animals
E. Diagnosis
 1. Malignant tumors are fast growing and invasive with poorly defined borders
 2. Look for metastases
F. Treatment
 1. Surgical excision (with wide margins) is the treatment of choice
 2. Radiation therapy is used when the tumor cannot be completely excised
 3. Hyperthermia treatment is used in combination with radiation or chemotherapy
 4. Chemotherapy is used best after incomplete excision. Agents used include vincristine, doxorubicin, cyclophosphamide, mitoxantrone, dacarbazine, carboplatin, and lomustine

II. Mast cell tumors (MCTs)
A. Cause
 1. Unknown
 2. Breeds at higher risk: boxers, Boston terriers, English bulldogs, English bull terriers, Chinese shar-peis, Labrador retrievers, golden retrievers. In boxers, MCTs are usually well-differentiated. Siamese cats have a high incidence of histiocytic MCT
 3. Chronic inflammation and viruses may play a role in development
B. Biologic behavior
 1. About half of dogs have well-differentiated, grade 1 tumors, which are cured with excision. Undifferentiated tumors are in up to 40% of patients and are aggressive
 2. Preputial, inguinal, perineal, oral, and aural tumors are more aggressive
 3. Slow-growing MCTs have a better prognosis
 4. Metastasis is to lymph nodes, spleen, and liver. The bone marrow may also be involved. Metastasis to the lungs is uncommon
 5. In cats, most are well-differentiated. Histiocytic MCT occurs in young cats and may spontaneously regress. Visceral MCTs are aggressive and metastasize
C. Clinical signs
 1. Dog: Solitary mass in skin of trunk, perineal area, extremities, or head and neck. Cat: Solitary mass on head and neck; about 20% of cats have multiple masses
 2. Usually well-defined and raised; can be hairless and ulcerated. If subcutaneous, they can resemble lipomas
 3. Visceral MCTs can occur in the spleen, intestine, liver, and lymphatics. Animals may present with anorexia, vomiting, and diarrhea
D. Diagnosis
 1. A CBC should be examined for evidence of circulating mast cells (more common in the dog). There may be a microcytic, hypochromic anemia if there is GI hemorrhage
 2. A bone marrow aspirate should be performed if there is suspected bone marrow involvement
 3. Abdominal radiographs may reveal hepatomegaly, splenomegaly, or abdominal lymph node enlargement
 4. A fine-needle aspirate of a mass is usually diagnostic. Histopathology is necessary to ensure that excision is complete and for grading the tumor

E. Treatment
1. Surgical excision (with wide margins) is the treatment of choice
2. Mast cells release histamine; give an antihistamine before surgery
3. If the tumor cannot be completely excised, a combination of radiation therapy or chemotherapy can be attempted. Also irradiate regional lymph nodes
4. Chemotherapy is recommended in systemic mastocytosis. Vinblastine, cyclophosphamide, or lomustine in combination are used
5. Give histamine type 2 (H_2)-antagonists (famotidine, ranitidine, cimetidine) to reduce gastric acid secretion. Give H_1-antagonists (diphenhydramine) to reduce inflammation associated with histamine
6. In cats, splenectomy may increase the survival, even if other organs are involved. Chemotherapy has not been well evaluated in cats

III. Skeletal neoplasias
A. Osteosarcoma (OSA)
1. About 85% of primary bone tumors in dogs are OSAs
2. OSA is usually aggressive and found in metaphysic of long bones. The radius is the most common site. Most have pulmonary metastatic disease
3. Large and giant breeds may be predisposed
4. In cats, OSA is less aggressive, and the hindlimb is more commonly affected
5. Treatment is amputation with chemotherapy. Cisplatin, carboplatin, and doxorubicin are frequently used for chemotherapy
6. The prognosis is poor if there are pulmonary metastases, an elevated alkaline phosphatase, or OSA is found in a young patient. Long-term prognosis is poor

B. Chondrosarcoma
1. About 5% to 10% of primary bone tumors are chondrosarcomas
2. Medium-sized to large-breed dogs are more commonly affected
3. Surgical resection increases survival, but long-term prognosis is still poor

C. Fibrosarcomas and hemangiosarcomas are the next most common bone tumors in dogs

D. Metastatic bone tumors
1. Carcinomas are more likely to metastasize to bone
2. Metastasis to bone usually causes tumors in the diaphysis; primary tumors are usually in the metaphysic
3. Prostatic carcinomas, transitional cell carcinomas, and mammary cell carcinomas tend to metastasize to bone

MAMMARY GLAND NEOPLASIA

I. Cause
A. Unknown; genetics or a virus may play a role
B. Dogs spayed before the first estrus have a greatly reduced risk
C. Administration of progestins increases the risk
D. Dogs that have had a benign mammary gland tumor are at higher risk for developing a mammary tumor of a different type

II. Clinical signs
A. Mass or swelling on the ventral thorax of abdomen
B. Metastatic lesions may cause dyspnea, bone pain, or lameness
C. May see anorexia and weight loss, especially in cats with inflammatory mammary carcinoma (IMC)

III. Diagnosis
A. Signalment
1. Risk increases after 6 years of age
2. Sporting breeds, poodles, Boston terriers, and dachshunds are at increased risk
3. In cats, most occur in intact females; Siamese have an increased risk

B. History: A mass is usually noted by the owner, or it may be an incidental finding

C. Physical examination
1. Most often occur in the caudal mammary glands
2. Inflammatory tumors have diffuse swelling, which may look like mastitis
3. Lymph nodes may be enlarged (superficial cervical, axillary, popliteal, inguinal)

D. Diagnostic imaging
1. Mammary tumors commonly metastasize to the lungs
2. Evaluate the iliac lymph nodes with radiographs or ultrasound

E. Cytology
1. Aspirates of the mammary tumor are not recommended as many have inflammation, which makes tumor grading difficult
2. Cytology can help differentiate a tumor from mastitis
3. Lymph nodes can be aspirated

F. Histology
1. About 50% are benign
2. Dogs can have multiple tumors of different types
3. Remove regional lymph nodes for histopathology. If lymph node involvement is noted, prognosis is poorer

IV. Treatment
A. Surgical
1. Surgery is *not* recommended for cases of IMC because it is difficult to remove all the affected tissue, and disseminated intravascular coagulation is often induced by surgery
2. Surgery is the treatment of choice for mammary gland tumors (except for IMC)
3. Wide excision is important
4. Lumpectomy can be performed if the tumor is very small and noninvasive
5. Simple mastectomy (removal of one gland) is relatively simple
6. Multiple glands may be removed if the tumor is extensive
7. When multiple, nonadjacent glands are involved, perform a complete unilateral mastectomy

B. Medical therapy has been used in conjunction with surgery to treat metastases
1. Efficacy has not been established

2. Cyclophosphamide and 5-fluorouracil have been used in dogs; cyclophosphamide and doxorubicin have been used in cats

V. Prognosis
 A. In cats, tumor size in important. Cats with tumors greater than 3cm in diameter have a poorer prognosis
 B. In dogs, histologic grade and stage are most important
 1. If the tumor is invasive or metastatic, the mortality rate is 80%
 2. Most deaths occur within 1 year of surgery
 3. About 26% with benign tumors develop new masses within 2 years of the initial surgery
 4. Poorly differentiated tumors have a poorer prognosis
 5. Ductular carcinomas metastasize more frequently compared with adenocarcinomas

SKIN AND SUBCUTANEOUS TISSUE TUMORS

I. Introduction
 A. More common in older dogs and cats
 B. Most common site of neoplasia in the dog; the second most common site in the cat
 C. Most skin tumors in dogs are benign; most in the cat are malignant
 D. Dog breeds at increased risk include the basset hound, boxer, bullmastiff, Scottish terrier, and Weimaraner; no breed predilection in the cat
 E. Most common tumors in young dogs are histiocytoma, transmissible venereal tumors, and viral papillomas
 F. Most common tumors in dogs include lipomas, MCTs, histiocytomas, and sebaceous gland adenomas; most common tumors in cats include basal cell tumors, squamous cell carcinomas, fibrosarcomas, and MCTs

II. Diagnosis
 A. Cytology
 1. Malignant vs. benign
 2. Epithelial, mesenchymal, or round cell neoplasm
 3. Inflammatory vs. noninflammatory
 4. Evaluate enlarged regional lymph nodes
 B. Biopsy
 1. Either incisional or excisional
 2. Submit all tumors removed for histopathology
 C. Radiographs
 1. Thoracic radiographs if malignancy is suspected
 2. Abdominal radiographs/ultrasound to evaluate involvement of liver and spleen (especially if MCT or hemangiosarcoma)

III. Types
 A. Papilloma (epithelial)
 1. Originates from the squamous epithelium. In puppies, there is a viral cause
 2. Cauliflower or wart-like mass; may bleed if traumatized. Usually single nodule but can be multiple if cause is viral
 3. Common in dogs; rare in cats. Viral-induced papillomas are usually on the head, eyelids, feet, or mouth and are contagious to other dogs. Some papillomas in older dogs can transform into squamous cell carcinoma
 4. In young dogs, papillomas regress spontaneously. Surgically remove if they do not regress
 B. Sebaceous gland tumors (epithelial)
 1. Originate from the epithelium of the sebaceous glands
 2. Common in older female spaniels and poodles; rare in cats
 3. Adenoma is usually a wart-like growth that is smooth, pink, and well-circumscribed. They are often ulcerated and bleeding. Sebaceous gland adenocarcinomas are invasive and very rare. Carcinomas metastasize to lymph nodes and lungs
 4. Surgical excision is the treatment of choice. Carcinomas may require radiation therapy and/or chemotherapy
 C. Perianal tumors (epithelial)
 1. Originate from the perianal glands (sebaceous glands surrounding the anus; also in skin of the tail, prepuce, thigh, and dorsum of back). They are dependent on the presence of testosterone
 2. Solitary or multiple; usually benign; common in older intact male dogs. Carcinomas are ulcerative and invasive. Carcinomas metastasize to lymphatics, iliac lymph nodes, and lungs
 3. Adenomas regress with castration. Adenocarcinomas should be radically excised; also treat with radiation or chemotherapy (carboplatin, mitoxantrone, and doxorubicin)
 D. Basal cell tumors (epithelial)
 1. Originate from basal cells of the epidermis and adnexa
 2. Usually solitary, firm, well demarcated, and pigmented. Found on the head, neck, and shoulders in the dog; anywhere in the cat (the most common skin tumor in cats)
 3. On cytology, cells are arranged in cords
 4. Common in older dogs and cats; cocker spaniels and poodles are at increased risk
 5. Usually benign; basal cell carcinomas are aggressive
 6. Surgical excision is the treatment. Treat carcinomas with radiation and chemotherapy
 E. Ceruminous gland tumors (epithelial)
 1. Originate from the ceruminous epithelium in the ear canal
 2. Usually brown tumors with cerumen production; small and located near the tympanic membrane
 3. More common in cats
 4. Total ear canal ablation may be necessary to excise. Irradiation is recommended with adenocarcinomas and incomplete resection. Chemotherapy includes cisplatin, carboplatin, mitoxantrone, and doxorubicin
 F. Squamous cell carcinoma (epithelial)
 1. Originates from the squamous epithelium. Occurs secondary to ultraviolet light exposure in hypopigmented areas
 2. Occur more frequently in white cats; on ear tips and nose. In dogs they occur primarily on the ventral abdomen, trunk, scrotum, and lips

3. Locally invasive; late to metastasize (to lymph nodes and lungs)
4. Surgical excision is the treatment if possible. Can also use radiation therapy or chemotherapy with cisplatin, carboplatin, bleomycin, mitoxantrone, or doxorubicin

G. Anal sac/apocrine gland adenocarcinoma (epithelial)
1. Originate from the apocrine glands that secrete into the anal sac
2. Can vary in size from very small to large masses protruding from the rectum
3. Most common in the older female dog. Metastases to regional lymph nodes are common
4. Often associated with hypercalcemia, and the secretion of parathyroid hormone–related protein
5. Treatment is surgical excision; also chemotherapy with carboplatin or mitoxantrone

H. Keratoacanthoma (epithelial)
1. Originates from the epithelium between hair follicles
2. Located on the neck, dorsal thorax, legs, and ventral abdomen. Can express a toothpaste-like material
3. Benign; solitary in most breeds, though multiple in Norwegian elkhounds and keeshonden
4. Treatment is surgical excision. Retinoid therapy for the multicentric form

I. Dermoid and epidermal inclusion cyst (epithelial)
1. Inclusion cysts are typically secondary to an occluded hair follicle. Dermoid cysts are a developmental defect
2. Benign
3. Treatment is surgical excision

J. Lipomas/liposarcomas (mesenchymal)
1. Originate from adipocytes
2. Lipomas are usually soft and well circumscribed. Liposarcomas are rare, usually solitary, infiltrative, firm, poorly circumscribed, and metastasize to the lungs and liver
3. Lipomas are more common in older spayed female dogs; the most common mesenchymal tumor in the dog. Rare in the cat
4. Lipomas may not need to be removed. Liposarcomas should be surgically removed and treated with radiation therapy if there are incomplete margins on histopathology

K. Fibrosarcoma (mesenchymal)
1. Originates in the fibrous connective tissue from fibrocytes or fibroblasts
2. Occurs in association with feline sarcoma virus or FeLV in cats; either sporadic, or at sites of vaccination. Prevalence of vaccine-associated fibrosarcomas is 1-3:10,000 cats
3. Usually on the head, trunk, or limbs
4. In older dogs and cats, usually solitary; in younger cats where associated with feline sarcoma virus, they are multiple
5. Locally invasive but late to metastasize
6. Treatment: Wide and deep surgical excision. Chemotherapy with doxorubicin or mitoxantrone

L. Hemangiosarcoma (mesenchymal)
1. Originates from the vascular endothelium
2. Solitary masses, usually on the limbs, flanks, or neck
3. More common in German shepherd dogs and golden retrievers
4. If the tumor is subcutaneous or involves muscle, prognosis is poorer
5. Treatment is by surgical excision. If it involves subcutaneous tissue, then also treat with doxorubicin

M. Histiocytoma (round cell)
1. From monocyte or macrophage cells in the skin
2. Usually on the head; round, alopecic, and pink. Look like a 'button"
3. Typically in young dogs (i.e., 1 to 3 years of age); do not occur in cats
4. Most spontaneously regress within 4 to 8 weeks
5. Surgically remove if they do not regress

N. Melanoma (round cell)
1. Originates from melanocytes or melanoblasts
2. Usually brown to black pigmented nodules and occurs more commonly on the face, trunk, feet, mucocutaneous regions, and nail beds
3. More common in dogs than in cats
4. Tumors in the skin are usually benign; tumors of mucocutaneous regions are usually malignant
5. Surgery is the treatment of choice. Recurrence and metastases are common

O. Transmissible venereal tumor (round cell)
1. Transmitted via mating or close contact
2. Occur on the external genitalia and face
3. May be multiple; friable, ulcerated, cauliflower-like masses
4. Treatment is surgery, vincristine chemotherapy, or radiation therapy

Supplemental Reading

Davis KM, Stone EA. Mammary gland neoplasia. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders , pp. 311-315.

Gilson SD, Page RL, Gamblin RM. Principles of oncology. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 283-291.

Graham JC. Soft tissue sarcomas and mast cell tumors. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 301-310.

Palmisano M, Miovancev M. Neoplasia of thoracic and pelvic limbs. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1176-1185.

Peterson JL. Tumors of the skin and subcutaneous tissues. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 316-326.

Vail DM. Lymphoid neoplasia. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 292-300.

Withrow SJ, Vail DM. *Small Animal Clinical Oncology,* 4th ed. St Louis, 2007, Saunders.

22 CHAPTER

Orthopedic Disorders

Patricia A. Schenck

It is not possible to provide a complete review of the anatomy, surgical approaches to the bones and joints, and surgical procedures in this review text. The reader is encouraged to review surgical techniques, approaches, and anatomy using a surgery text.

FRACTURES OF THE SKULL

I. Zygomatic arch fracture
 A. Preoperative considerations
 1. Perform a neurologic examination
 2. Confirm that the optic nerve and vision is intact before surgery
 3. Computed tomography (CT) provides the best assessment
 B. Surgical procedure: Reduce fractures that cause compression of the eye
 C. Postoperative care and complications: Monitor neurologic function. Degenerative joint disease (DJD) of the temperomandibular joint (TMJ) may result long-term. Prognosis is good

II. Extracranial fractures: Fractures of the nuchal crest, sagittal crest, or frontal sinus
 A. Preoperative considerations: Perform neurologic examination
 B. Treatment: Most are managed conservatively. Surgery is performed if displacement is severe
 C. Postoperative care and complications: Monitor neurologic function. Subcutaneous emphysema may occur secondary to frontal sinus fracture

III. Intracranial fractures
 A. Preoperative considerations
 1. Perform a neurologic examination
 2. Most are closed fractures
 3. Calvarial fractures are usually associated with central nervous system (CNS) compromise
 B. Surgical procedure: Elevate depressed calvarial fractures, and remove comminuted pieces
 C. Postoperative care and complications: Monitor neurologic function. Prognosis is guarded for neurologic recovery

FRACTURES AND DISLOCATIONS OF THE MANDIBLE

I. Anatomy
 A. About 15% of all fractures in cats are of the mandible
 B. The mandibular canal contains the mandibular artery and vein and the mandibular alveolar nerve

II. Clinical signs: Asymmetry of the jaw, oral hemorrhage and pain, crepitus, concurrent head and thoracic trauma

III. Diagnosis: Based on history and radiographs; CT can provide a three-dimensional (3-D) impression

IV. Surgical procedures
 A. Preoperative considerations: Monitor neurologic function, and check for diaphragmatic hernia, pneumothorax, and other conditions
 B. Anesthetic considerations: Place an endotracheal tube through a pharyngotomy incision. Give antibiotics because most mandibular fractures are open
 C. Surgical principles: Restore normal dental occlusion. Intramedullary pinning is not recommended
 D. Postoperative care: Maintain nutrition with an esophagostomy or gastrostomy feeding tube. If not using a feeding tube, feed a soft gruel for 4 weeks post surgery. Flush the mouth daily with dilute chlorhexidine solution
 E. Complications: Malocclusion is the most important complication; osteomyelitis occurs rarely

V. Mandibular symphyseal separations
 A. Occurs often in cats
 B. Wire stabilization is the technique of choice

VI. Mandibular body fractures
 A. Create a muzzle using tape (Figure 22-1)
 1. Can be used if there is minimal displacement of fragments
 2. Difficult to do in cats or in brachycephalic breeds
 3. Feed soft gruel
 B. Maxillary-mandibular fixation: Either wire the maxilla to the mandible or use acrylic bonding of the canine teeth to keep the mouth closed
 C. Interfragmentary wiring: For fracture fragments that are stable without loss of bone or comminution
 D. Intraoral acrylic splint
 E. External skeletal fixation: Best used for fractures that are open, comminuted, or involve bone loss
 F. Bone plating

VII. Mandibular ramus fractures
 A. Usually do not require surgical treatment because displacement is minimal
 B. Condylectomy can be performed in those that develop an inability to open the mouth

VIII. TMJ dislocations
 A. Usually occurs from trauma

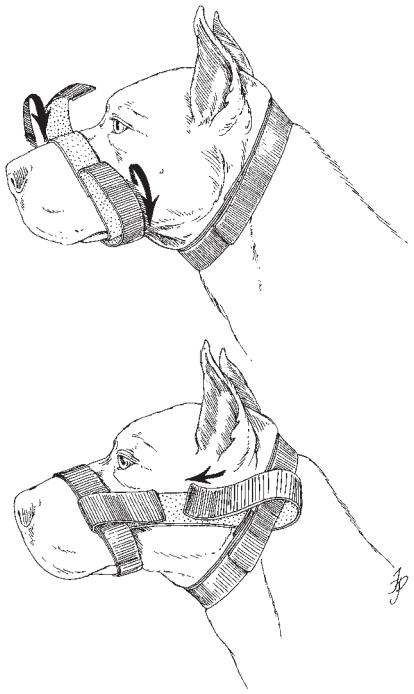


Figure 22-1 Procedure for creating a tape muzzle. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

B. Use closed reduction to replace, then stabilize with either a muzzle of tape, or maxillary-mandibular fixation

IX. TMJ dysplasia
A. Jaw locks in the open position. Reported in Irish setters, cocker spaniels, and basset hounds
B. May require condylectomy or resection of the zygomatic arch

FRACTURES OF THE MAXILLA

I. Etiology
A. Most are the result of trauma
B. More likely in young dogs and cats
II. Clinical signs include asymmetry of the maxilla, oral pain and bleeding, nasal hemorrhage
III. Diagnosis
A. History and radiographs. More than one fracture may be present
B. CT gives a 3-D view
IV. Preoperative considerations
A. Manage concurrent head, airway, and thoracic trauma. Maintain an airway and treat shock
B. Complete a neurologic examination
V. Anesthetic considerations
A. Place endotracheal tube through a pharyngotomy incision
B. Give antibiotics because many maxillary fractures are open
VI. Surgical fixation
A. Restore dental occlusion
B. Maintain patent nasal passages
C. Midline maxillary separations (traumatic cleft palate)
1. Occurs frequently in cats
2. Wide defects should be surgically closed
D. Maxillary body fractures: Most do not require surgical treatment. Stabilization techniques used for mandibular fractures can be used for maxillary body fractures
E. Postoperative care: Maintain adequate nutrition. Use gastrostomy or esophagostomy feeding tube. If not using a feeding tube, feed soft gruel
F. Complications include dental malocclusion and osteomyelitis

NEOPLASIA OF THE MAXILLA AND MANDIBLE

I. Causes
A. The oropharyngeal region is the fourth most common site of malignant neoplasia in the dog
B. The most common oral neoplasms in the dog are malignant melanoma, squamous cell carcinoma (SCC), fibrosarcoma, and epulides. SCC is the most common in cats
C. Boxers, golden retrievers, and cocker spaniels are predisposed to oral tumors. Small-breed dogs are more prone to develop malignant melanomas, and large-breed dogs are more prone to SCC and fibrosarcoma
D. Surgical resection is the first line of therapy for all oral tumors
II. Diagnosis
A. History includes drooling, halitosis, and dysphagia. Deformity of the muzzle may be present. Most are painful, so anorexia is common
B. Physical examination: Consider sedation. Most metastasize via the lymphatic system so examine lymph nodes
C. Diagnostic evaluation includes complete blood cell count, chemistry profile, radiographs of skull and chest. CT and magnetic resonance imaging (MRI) are helpful in evaluating the extent of invasion. Biopsy is important in determining treatment
III. Tumor types
A. Benign nonodontogenic neoplasms
1. Epulis
a. Fibrous tumor originating from the periodontal ligament
b. Rare in cats, common in dogs. The boxer is predisposed
2. Other tumors include fibroma, hemangioma, lipoma, chondroma, osteoma, and histiocytoma
B. Malignant nonodontogenic neoplasms
1. Malignant melanoma
a. Often is locally invasive with early metastasis
b. May be pigmented or nonpigmented
c. Usually ulcerated, so oral bleeding and halitosis are common
d. Treatment is complete surgical resection. Radiation therapy has moderate success. Chemotherapy is not effective

2. Squamous cell carcinoma (SCC)
 a. Second most common oral tumor in dogs, most common tumor in cats
 b. Nontonsillar SCC is locally invasive and slow to metastasize. Tonsillar SCC is very aggressive, with early metastasis to lymph nodes and lungs
 c. Wide surgical resection is the treatment of choice, with or without radiation therapy. Chemotherapy may be added to treatment
 d. Prognosis is guarded as recurrence is high
3. Fibrosarcoma
 a. Third most common oral tumor in dogs; second most common in cats
 b. Slow-growing, locally aggressive, late to metastasize
 c. Local recurrence is common
 d. Surgical resection is the treatment of choice. Radiation and chemotherapy can also be used in conjunction
4. Other malignant nonodontogenic neoplasms include osteosarcoma (OSA), adenocarcinoma, transmissible venereal tumor, mast cell tumor, hemangiosarcoma, and tonsillar lymphosarcoma
5. Malignant odontogenic neoplasms
 a. Ameloblastoma arises from the dental laminar epithelium. Rare tumors but more common in younger dogs
 b. Odontomas can invade all dental tissues and are rare
 c. Surgical resection is the treatment of choice

IV. Surgery
 A. Preoperative considerations
 1. Knowledge of anatomy is necessary
 2. Maxillectomies are associated with significant blood loss, so have a source of blood replacement
 3. Administer nonsteroidal antiinflammatory drugs (NSAIDs) and fentanyl patches to minimize postoperative pain
 4. Use cuffed endotracheal tube
 5. Give antibiotics
 B. Objectives are to resect completely the neoplasm and preserve local blood supply
 C. Procedures for surgery include maxillectomy (unilateral or bilateral), hemimaxillectomy, and mandibulectomy
 D. Postoperative care
 1. Pain control
 2. Elizabethan collar to prevent self-mutilation
 3. Feed soft gruel for 1 month post surgery. Flush the oral cavity after eating. Maintain nutrition
 4. Reevaluate every 3 months for the first year. Watch for metastasis
 E. Complications
 1. Transient facial edema resolves after a few weeks
 2. Nasal discharge, facial swelling, noisy respiration, and inappetence often occur
 3. The most common complication is dehiscence

FRACTURES AND DISLOCATIONS OF THE SPINE

I. Atlantoaxial instability
 A. Anatomy
 1. A pivot joint that allows the head to rotate around an axis
 2. The dens is on the ventral surface of C2 (the axis) that projects into the floor of C1 (atlas)
 B. Causes
 1. Congenital causes are most common and are seen in young, small and toy-breed dogs. Instability arises from malformation of the dens, lack of ligamentous support, or congenital absence of the transverse or atlantoaxial ligaments
 2. Acquired causes are the result of trauma and can happen at any age or breed of dog or cat
 C. Clinical signs
 1. Vary from pain to ataxia or tetraplegia. The severity is dependent on the degree of subluxation
 2. If the dens luxates dorsally into the spinal cord, the signs are more severe
 3. If the spinal cord suppression is severe, respiratory arrest and death can occur
 D. Diagnosis
 1. Radiographs are necessary and reveal a widened space between the dorsal arch of C1 and the dorsal spine of C2
 2. CT and MRI are not required
 E. Surgical procedures
 1. Do not flex the spine, which can exacerbate cord compression
 2. Objectives are to remove the fractured or ununited dens, stabilize the C1-C2 articulation, and prevent spinal cord injury
 3. A dorsal approach or ventral approach can be used. The ventral approach is more difficult but has a higher success rate
 4. Complications include infection, dysphagia, laryngeal paralysis, or surgical failure
 5. Manage pain, administer antibiotics, and place an Elizabethan collar for 2 weeks. Restrict exercise for 4 to 6 weeks

II. Caudal cervical spondylomyelopathy (wobbler syndrome)
 A. Anatomy
 1. The dorsal components that play a role include the dorsal vertebral lamina, the articular facets and joint capsule, and the ligamentum flavum
 2. The ventral components that play a role include the vertebral bodies, the dorsal fibers of the annulus fibrosus of the intervertebral disc, and the dorsal longitudinal ligament
 B. Causes
 1. Two populations of dogs get wobbler disease. About 10% to 15% are young Great Danes with osseous malformations of the cervical spine. The remainder are middle-aged to older dogs with acquired disease secondary to cervical vertebral instability. Doberman pinschers make up about 80% of this group. Labradors and dalmatians are also predisposed.

2. Pathologic changes
 a. With congenital osseous malformation, there is malformation or malarticulation of the articular facets and vertebral bodies, which causes dorsal and lateral stenosis of the spinal canal. C3 to C7 bodies are most often affected. Stenosis is seen and gets worse with age. Heredity, nutritional imbalance, or trauma may play a role
 b. Vertebral tipping is seen in middle-aged to older patients. There is a malposition of the vertebral body caudal to the affected intervertebral disc. The cranial aspect of the affected vertebra is displaced dorsally, causing spinal compression. The C5 to C6 and C6 to C7 spaces are most commonly affected
 c. Chronic degenerative disc disease with cervical vertebral instability occurs most in Doberman pinschers and is caused by concurrent dorsal annulus and dorsal longitudinal ligament hypertrophy. The caudal cervical intervertebral disc spaces are affected most commonly
 d. Ligamentum flavum hypertrophy causes dynamic dorsal spinal canal compression and is associated with vertebral arch abnormalities
 e. Hourglass compression is associated with dorsal, ventral, and lateral compression and occurs most commonly in young Great Danes

C. Clinical signs
 1. A chronic, progressive history of neck pain, hypermetria, ataxia, and tetraparesis is common
 2. Compression worsens with neck extension
 3. The clinical signs may wax and wane; occasionally there will be an acute deterioration
 4. Ataxia is usually worse in the rear limbs. Proprioceptive deficits are present, with paraparesis progressing to tetraparesis. In the thoracic limb, there is usually muscle atrophy of the spinatus muscle of the shoulder

D. Diagnosis
 1. Differentials include degenerative spinal cord disease, ischemic myelopathy, discospondylitis, congenital spinal cord disease, inflammatory CNS disease, spinal neoplasia, brachial plexus tumor, subarachnoid cysts, and trauma. Ischemic myelopathy is not associated with cervical pain, however
 2. Myelography is helpful in identifying the site of compression
 3. CT may be helpful in identifying dorsal arch abnormalities and osseous malformations in the Great Dane
 4. MRI is the gold standard for imaging of the spine because MRI gives the greatest detail of soft tissue structures

E. Surgical procedures
 1. The three primary decompressive surgeries are ventral decompression using a ventral slot technique, ventral distraction and fusion using a polymethylmethacrylate (PMMA) plug, and dorsal decompression using a dorsal laminectomy
 2. The choice of procedure is based on where the compression is located (dorsal or ventral), the number of spaces involved, and whether it is dynamic or static

F. Postoperative care and complications
 1. Manage pain (Fentanyl patch); give NSAIDs
 2. Administer antibiotics for 5 days post surgery
 3. Provide nursing care for the recumbent patient
 4. Restrict activity for 3 to 6 months post surgery. Use a harness rather than a collar for a dog
 5. Obtain radiographs monthly until there is complete bony fusion at the atlantoaxial joint (usually in 8-12 weeks)
 6. There is usually about an 80% return of function, but about 30% have recurrences within 2 years

III. Spinal fractures and dislocations

A. Introduction
 1. Most are due to trauma
 2. Repair depends on the region of the lesion, amount of neurologic dysfunction, body size, and other injuries
 3. The thoracolumbar and lumbosacral junctions are prone to fracture and luxation

B. Causes
 1. Hyperextension is due to direct trauma to the dorsal spine, with collapse of the dorsal compartment
 2. Hyperflexion results in a wedge compression fracture of the vertebra, sparing the dorsal compartment. These fractures are usually stable
 3. Compression occurs with an axial load force, and fragments and extruded nucleus pulposus can be driven into the spinal cord
 4. Rotation is usually associated with hyperextension, and disruption of both ventral and dorsal compartments occur

C. Clinical signs may range from pain or proprioception loss to loss of motor function

D. Diagnosis
 1. Perform a complete physical examination, including a neurologic examination
 2. Obtain thoracic and abdominal radiographs. Myelography is not indicated. CT is best for identifying bony pathology; MRI is best for soft tissue visualization
 3. Most important for prognosis is the presence of deep pain. If deep pain sensation is intact, there is an 85% to 90% chance of recovering normal neurologic function. If deep pain is absent, there is only a 15% chance of neurologic function recovery
 4. Immobilize the patient to prevent additional spinal cord damage

E. Preoperative considerations
 1. If the fracture is stable with minimal displacement and the patient has good motor function, the patient can be managed without surgery
 2. Surgery is indicated if the fracture is unstable or significantly displaced, if motor function is diminished, or there is evidence of declining neurologic function

F. Surgical procedures
 1. For cervical fractures, most occur at the dorsal spine or body of C2. A ventral approach to the cervical spine provides the best bone structure for fixation
 2. The thoracolumbar junction and lower lumbar-lumbosacral space are the most common locations of fracture or luxation in the thoracic and lumbar spine. The most common techniques are dorsal spinous process plating using plastic spinal plates and pin and PMMA fixation
 3. Fractures of L6, L7, and the sacrum are common; signs are related to sciatic, femoral, and sacral nerve deficits. A dorsal approach is used for fixation

G. Postoperative care and complications
 1. Minimize pain, begin antibiotic therapy, and provide nursing care for the recumbent patient
 2. Begin physical therapy soon after surgery
 3. Make sure there is urinary control; if not, express the bladder every 6 hours. Avoid indwelling urinary catheters
 4. If deep pain sensation is present, about 85% will regain near-normal neurologic function

NEOPLASIA OF THE AXIAL SKELETON

I. Causes
 A. OSA and chondrosarcoma are the most common neoplasms
 B. Hemangiosarcoma and fibrosarcoma should also be considered
 C. Multilobular osteoma is the most common tumor of the skull

II. Clinical signs
 A. Usually presented for a swelling over a bone
 B. Neoplasias of the rib may lead to respiratory signs
 C. Skull tumors may lead to neurologic signs
 D. Pelvic tumors may result in constipation

III. Diagnosis
 A. Radiographic signs may range from primarily lytic to proliferative lesions
 B. Polyostotic lytic lesions are seen with lymphoma and multiple myeloma
 C. Determine whether metastases are present; especially check regional lymph nodes and lungs
 D. OSA or multilobular osteoma of the cranium appears as proliferative bony lesion of flat bones
 E. Cerebrospinal fluid evaluation is usually normal but may reveal increased levels of protein and elevated pressure with vertebral neoplasia
 F. Myelography and CT can determine the exact site of the tumor and how much spinal cord compression is present
 G. Bone biopsy is necessary for a histopathologic diagnosis

IV. Treatment
 A. Rib neoplasia
 1. Completely remove the mass with wide normal margins
 2. Prevent abnormal chest wall movement
 3. Prevent pneumothorax
 4. Monitor for hemorrhage, seroma formation, and pneumothorax. Manage pain
 5. Neoplasms are usually malignant. Consider chemotherapy if excision was not complete
 6. Metastases may have occurred even if the tumor has been resected
 B. Pelvic neoplasia
 1. The ileal wing can be resected for localized tumors. Avoid hemorrhage and nerve damage
 2. Monitor for seroma formation and infection
 3. Manage pain
 4. Consider chemotherapy if the tumor is malignant
 C. Vertebral neoplasia
 1. Remove as much of the tumor as possible and decompress the spinal cord
 2. Administer dexamethasone prior to surgery to minimize spinal cord edema from manipulation
 3. Perform multiple neurologic examinations
 4. Monitor for urine retention
 5. Consider chemotherapy
 6. The prognosis for malignant vertebral tumors is poor

FRACTURES OF THE SHOULDER

I. Anatomy
 A. Fractures are often associated with brachial plexus injuries or soft tissue injury
 B. Suprascapular nerve crosses the scapular neck beneath the acromion
 C. Cephalic vein is on the superficial craniolateral aspect of the greater tubercle of the humerus
 D. Circumflex humeral vessels are distal to the teres minor, beneath the deltoideus muscle

II. Diagnosis
 A. Clinical signs include lameness of the forelimb and pain or crepitus on palpation of the scapulohumeral joint
 B. Radiography is required for diagnosis. CT is useful because of the 3-D views

III. Fractures of the scapula
 A. Fracture of the scapular body is most common
 B. If there is minimal displacement, treat with strict cage confinement
 C. Because there are many tendons and muscles around the scapulohumeral joint, osteotomy of the acromion or greater tubercles may be required. These can then be reattached by screws
 D. Scapular body fractures are often transverse or oblique. Because the scapula is thin, treat with cage rest if at all possible
 E. Fractures of the spine of the scapula do not require surgery
 F. Fractures involving the acromion require surgery with tension band or lag screw fixation
 G. Fractures of the scapular neck require surgery for fixation. Be careful to protect the suprascapular nerve
 H. Supraglenoid tubercle fractures require surgical fixation. In immature animals, the secondary center of ossification of the supraglenoid tubercle can be confused with a fracture

I. Glenoid fractures require surgical fixation
J. The prognosis is good for healing and normal function if there is good stabilization
K. Restrict activity for about 8 to 12 weeks
L. Complications include suprascapular nerve injury, osteoarthritis (OA), and decreased limb function. Suprascapular nerve injury results in atrophy of the supraspinatus muscle

IV. Proximal humeral fractures
A. These fractures are uncommon but occur mostly in immature animals (Salter-Harris type I, II, or III fractures). The physis of the proximal humerus is radiographically closed by 10 months of age
B. If there is a proximal humeral fracture in an older dog, evaluate for bone lysis or cortical thinning, which could indicate OSA
C. Surgery is required. Repair is usually with Steinmann pins and wire
D. Avulsion fractures of the greater or lesser tubercle occasionally occur in immature animals
E. For Salter-Harris I or II fractures, do a craniolateral approach. In young animals, use Steinmann pins and Kirschner wires. In older animals, use lag screws and Kirschner wire
F. For Salter-Harris III fractures, in young animals, use lag screws and Kirschner wire. In older animals, screws and a T plate can be used
G. Fractures of the humeral neck occur in older animals. Stabilize with a T plate or with Rush pins or Kirschner wires. Restrict to cage rest until signs of healing are seen on radiographs. Malunion occurs rarely. If there is good stabilization, these fractures heal rapidly

SCAPULOHUMERAL LUXATION

I. Causes
A. Occurs uncommonly
B. Medial luxation is most common, especially in small-breed dogs
C. Lateral luxation occurs in larger dogs

II. Clinical sign is forelimb lameness

III. Diagnosis is based on physical examination and radiography

IV. Closed reduction
A. Medial luxation
1. Flex elbow and pull limb laterally while exerting pressure on the scapular spine
2. Use general anesthesia
3. Place in a Velpeau sling for 2 weeks
4. Restrict exercise for another month. Swimming is a good exercise
B. Lateral luxation
1. Use general anesthesia
2. Flex elbow and extend the shoulder while rotating the humeral head upward
3. Use spica splint for 2 weeks

V. Open reduction
A. Use general anesthesia
B. Open reduction can be challenging and involves surgery to stabilize the joint
C. Postoperative care involves pain control, minimizing postsurgical inflammation, and encouraging movement of the distal extremity. Provide strict crate confinement for 3 weeks with leash walks
D. The prognosis is good if stabilization is adequate

FRACTURES OF THE HUMERUS

I. Anatomy
A. The radial nerve lies within the musculospiral groove of the humerus
B. On the lateral side, identify the lateral head of the triceps, the brachialis, the brachiocephalicus, and acromial head of the deltoid muscles. The radial nerve is also more lateral
C. On the medial side, identify the medial head of the triceps, the biceps brachii, and the median and ulnar nerves

II. Causes. Most are due to trauma (hit by a car) or a fall from excessive heights

III. Diagnosis
A. Diagnosis is based on radiographic findings
B. Check for other thoracic trauma such as pneumothorax, diaphragmatic hernia

IV. Proximal humeral physeal fractures
A. Seen in young dogs before physeal closure takes place
B. Surgery is usually required for fixation
C. Use a cranial approach and fix with Kirschner wires or Steinmann pins
D. Restrict activity but encourage range of motion activity

V. Proximal diaphyseal fractures
A. Least common diaphyseal fracture
B. Evaluate brachial plexus and radial nerve
C. Many occur secondary to metabolic bone disease
D. Surgery is necessary
E. Use a cranial approach. A single intermedullary pin may not provide rotational stability. Can use two Rush pins, Steinmann pins, or a bone plate
F. Encourage early range of motion with restricted exercise

VI. Diaphyseal fractures
A. These fractures are often spiral and can entrap the radial nerve
B. Muscle contraction causes overriding of fragments
C. Closed reduction can be attempted early after injury
D. For surgery, use a lateral approach
E. In small breeds, a combination of pins, wires, or external fixation can be attempted. When using pins, retrograde the pins into the proximal fragment from the fracture site
F. In large breeds, interlocking nails have been used. Plate fixation can be successful but is difficult because of the vessels and nerves present. Medial plate placement is easier
G. If external fixation is used, remove it in 4 to 6 weeks. Remove intramedullary pins following fracture healing

VII. Supracondylar fractures
A. Rigid internal fixation is necessary
B. Steinmann pins or double Rush pins can be used. In larger dogs, small bone plates can be used

VIII. Condylar fractures
 A. Most condylar fractures involve the lateral portion of the condyle, which carries most of the force through the elbow joint because of the articulation with the radial head
 B. Spaniels and rottweilers have a heritable defect in which the humeral condyle does not completely ossify. This predisposes them to this fracture
 C. Surgery is usually necessary
 D. Transcondylar lag screws with Kirschner wire are used. Using crossed Kirschner wires is not recommended
 E. Arthritis and reduced range of motion are common complications
IX. Intercondylar fractures of the humeral condyles
 A. These are very difficult to repair, as the condyles are split, in addition to the supracondylar fracture
 B. Fix the two condyles together first, then fix the supracondylar fracture
 C. Lameness and OA are common complications

FRACTURES AND GROWTH DEFORMITIES OF THE RADIUS AND ULNA, LUXATION OF THE ELBOW

I. Fractures of the radius and ulna
 A. Introduction
 1. Commonly seen
 2. Usually the result of trauma or from falling or jumping
 3. Open fractures of the distal part of the radius and ulna are common
 B. Anatomy
 1. The radius is the main weight-bearing bone of the forelimb and is shorter than the ulna. The ulna is the longest bone in the body
 2. The radial and interosseous arteries provide the main arterial supply. The radial, median, and ulnar nerves supply the antebrachium and paw
 C. Preoperative considerations
 1. Evaluate for concurrent injuries
 2. Evaluate neurologic function
 D. General objectives of surgery
 1. Allow early return to weight bearing
 2. Preserve neurovascular structures
 E. General postoperative care and complications
 1. Use a soft padded bandage for 3 to 10 days to reduce postoperative swelling
 2. Reevaluate with radiographs every 3 to 4 weeks. Restrict activity until the fracture has healed
 3. Complications include delayed healing and nonunion. If the fracture has not been stable, DJD can occur. If the animal is immature, there may be premature closure of the growth plates
 F. Olecranon fractures
 1. The triceps attached to the olecranon. Counteract the forces of the triceps by using the tension band principle and converting it into a compressive force
 2. Use small intramedullary pins or K-wires across the fracture, then place wire around the pins in a figure-eight fashion
 G. Trochlear notch fractures
 1. Because this is an articular fracture, there must be good alignment of the fracture with rigid fixation
 2. Counteract the forces of the triceps by using the tension band principle
 3. Use intramedullary pins, K-wires, or bone plates. Contour the bone plate to the caudal or caudolateral side of the ulna
 H. Radial head fractures
 1. Precise reduction with rigid fixation is necessary
 2. Use K-wires and lag screws to fix
 I. Radial neck and proximal physeal fractures
 1. In immature animals, stabilize without compression to prevent premature closure of the growth plate
 2. Stabilize so that the radial head articulates properly with the humeral condyle
 3. Use K-wires. Do not penetrate the articular surface of the radius
 4. Remove the K-wires in 3 to 4 weeks
 J. Monteggia fractures
 1. Refers to a fracture of the ulna with a radial head luxation
 2. Stabilize the ulnar fracture and reduce the radial head luxation
 K. Mid-shaft radial and ulnar fractures
 1. Maintain proper angulation, rotation, and length of the limb
 2. Prevent synostosis of the radius and ulna in immature animals
 3. Closed reduction and cast fixation
 a. Used for minimally displaced transverse fractures
 b. Flex the elbow in a functional angle, and place the carpus is a slight varus position
 c. Apply a fiberglass cast, working from distal to proximal
 4. External fixation is used for comminuted fractures and simple fractures
 a. Reduce the fracture closed if possible
 b. Place three or four pins on each side of the fracture line
 L. Plate fixation for distal metaphyseal fractures
 1. Occur primarily in small dogs
 2. High incidence of nonunion if the fracture is not stable
 3. Align the fracture with compression, and insert a cancellous bone graft
 M. Fractured styloid process of the ulna
 1. Reduce and stabilize the fracture with K-wires and wire in a figure-eight configuration
 2. Splint for 3 to 4 weeks postoperatively
II. Growth deformities of the radius and ulna
 A. Anatomy
 1. Deformities result from trauma and disruption of the blood supply to the physis, with synostosis of the radius and ulna
 2. The physes of the radius and ulna close at about 7 to 9 months of age in dogs

3. The distal ulnar physis contributes about 85% to the longitudinal growth, and the proximal physis (olecranon) contributes about 15% to the growth of the ulna
4. The distal radial physis contributes about 60% and the proximal radial physis contributes 40% to the longitudinal growth of the radius
5. The radius and ulna must grow in a synchronous fashion to attain a normal shape

B. Preoperative considerations
1. Early recognition and treatment are important
2. Obtain radiographs and determine whether physes are open or closed

C. General postoperative care and complications
1. In immature dogs, splint the limb, and reevaluate radiographically every 3 weeks
2. The prognosis is guarded, especially for mature dogs with severe deformities

D. Surgical procedure to correct premature closure of the distal ulnar physis
1. In immature dogs, remove a section of the ulna to allow unrestrained growth of the radius, and prevent regrowth by placement of a fat graft
2. In mature dogs, there is cranial or medial bowing, carpal valgus, limb shortening, and malalignment of the radius/ulna in the elbow
3. Objectives are to correct the angular deformities, and maintain as much limb length as possible
4. Perform an osteotomy of the radius at the point of maximal curvature

E. Surgical procedure to correct premature closure of the proximal radial physis
1. Usually not recognized until after the bone growth of the radius is finished
2. There is distal luxation of the radial head from the humerus, and the leg is straight
3. The objective is to articulate the radial head with the humerus and ulna

F. Surgical procedure to correct premature closure of the distal radial physis
1. In the immature dog with complete closure, there is distal luxation of the radial head, and the limb is shortened. The leg remains straight, and the radius and ulna bow rarely. The objective is to remove a section of the radius to allow unrestricted growth of the ulna
2. In the immature dog with partial lateral closure, there is carpal valgus with external rotation, cranial and medial bowing of the forelimb, and shortening of the limb. The objective is to remove the closed portion of the distal radial physis and prevent bony bridging of the removed physis
3. In mature dogs, the objective is to reestablish congruity to the elbow joint and to correct the angular deformity of the limb

III. Traumatic luxation of the elbow

A. Lateral luxation is common because the medial condyle of the humerus is larger which prevents medial luxation

B. Clinical signs include acute non-weight-bearing lameness; the foot and antebrachium are abducted, and flexion and extension of the elbow are not possible

C. Diagnosis is via radiography

D. Most elbow luxations can be treated by closed reduction if treatment is initiated within the first 3 days after the injury (Figure 22-2)

E. If elbow fractures are present, then surgery is indicated. Surgical reduction is difficult

F. Keep the elbow extended to maintain reduction, obtain radiographs to confirm reduction. Put in a lateral splint to maintain elbow extension. Maintain the splint for 2 weeks, then allow leash walks for another 2 weeks

FRACTURES AND DISLOCATIONS OF THE CARPUS

I. Introduction

A. Usually the result of trauma. Isolated fractures of the carpus are rare, usually occurring in greyhounds or working dogs

B. Fractures usually involve the articular surface so rigid fixation is necessary

II. Anatomy

A. Osseous structures
1. The seven bones are arranged in two rows. The proximal row includes the radial, ulnar, and accessory carpal bones. The distal row consists of the C1, C2, C3, and C4 carpal bones
2. The radial bone is the largest, is located medially, and articulates with the radius proximally, and with C1, C2, C3, and C4 distally
3. The ulnar carpal bone is lateral and articulates with the radius and ulna proximally, the accessory carpal bone on the palmar side, and with C4 and the 5th metacarpal bone distally
4. C4 is the largest bone of the distal row, and it articulates with the 4th and 5th metacarpal bones

B. Articulations
1. The antebrachiocarpal joint is between the distal radius and ulna and the proximal row of carpal bones. It provides about 70% of the range of motion
2. The middle carpal joint is between the proximal and distal row of carpal bones, and it provides about 25% of the range of motion
3. The carpometacarpal joint is between the distal row of carpal bones and the metacarpal bones, and it provides only about 5% of the range of motion
4. The intercarpal joints are those between the carpal bones. There is little motion in these joints

C. Ligamentous structures
1. There is no continuous collateral ligament that spans all three joints
2. The radial collateral ligament spans from the styloid process of the radius to the radial carpal bone
3. The ulnar collateral ligament spans from the styloid process of the ulna to the ulnar carpal bone
4. The flexor retinaculum supports the palmar part of the carpus

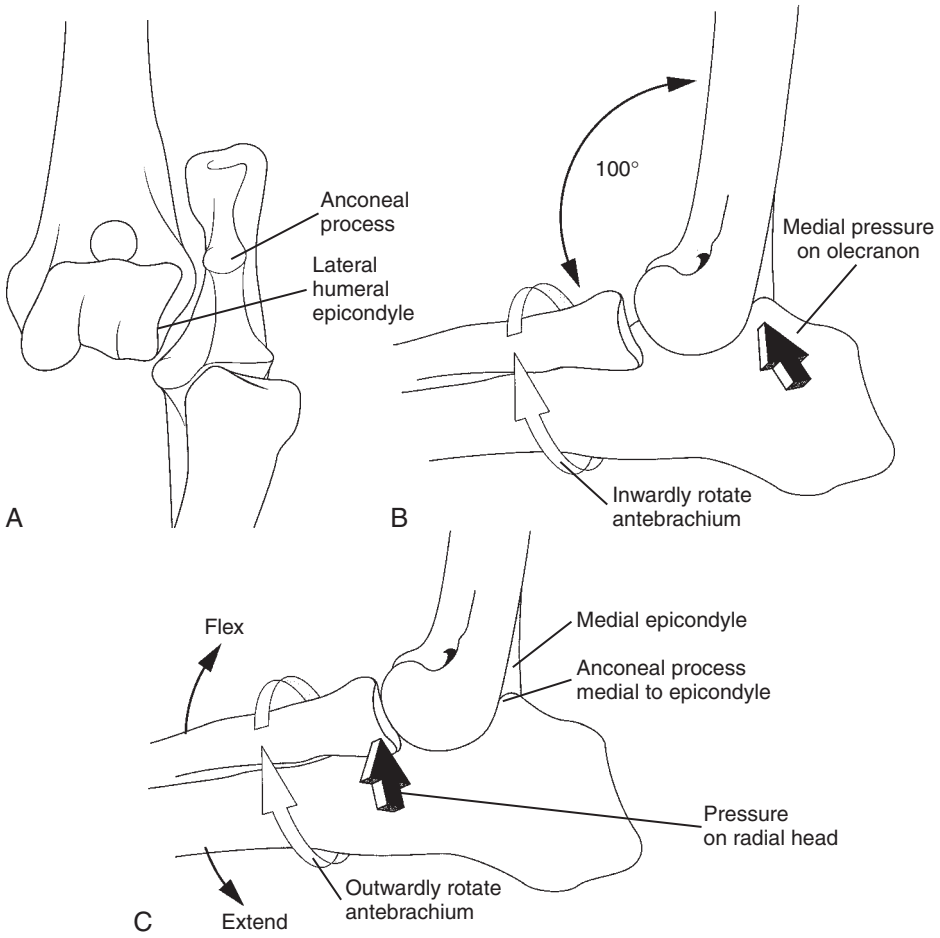


Figure 22-2 **A,** For closed reduction of a laterally luxated elbow **(B)**, flex the elbow and inwardly rotate the antebrachium to hook the anconeal process into the olecranon fossa. **C,** Then extend the elbow slightly and abduct and outwardly rotate the antebrachium while placing pressure on the radial head. (From Fossum TW. *Small Animal Surgery,* 3rd ed. St Louis, 2007, Mosby.)

5. The palmar carpal fibrocartilage crosses the palmar surface and attaches to all the bones except the accessory carpal bone. It also attaches to the metacarpals

II. Fractures of the radial carpal bone
 A. Most often occur in working dogs resulting from jumps or falls. Fractures may be chip fractures, slab fractures, or avulsion fractures rarely. Lameness is noted immediately following the injury. Bone fragments rarely reattach
 B. Nondisplaced fractures can be treated with a splint for 6 to 8 weeks
 C. Surgery is indicated to remove small fracture fragments. Larger fragments can be fixed using screws or Kirschner wires. A splint is used for several weeks postoperatively. Restrict exercise for 6 to 8 weeks. OA is a common sequel

III. Fractures of the accessory carpal bone
 A. Uncommon except in racing greyhounds
 B. These are usually avulsion fractures and need internal fixation
 C. Use screws and Kirschner wires
 D. Splint for 4 to 6 weeks postoperatively, and restrict exercise for 12 to 16 weeks

IV. Fractures of the ulnar carpal bone and C1, C2, C3, or C4
 A. Very rare
 B. Most are small chip fractures from hyperextension injury
 C. Treatment is fragment removal, splinting, and exercise restriction

V. Luxations, subluxations, and hyperextension injuries of the carpus
 A. Clinical signs and diagnosis
 1. Most common injury of the carpus in nonworking dogs; usually the result of a fall or jumping from a height. Tears or the palmar joint capsule, ligaments, and fibrocartilage also occur with the fracture
 2. Most have acute, non–weight-bearing lameness, with soft tissue swelling. Carpal hyperextension is present, so the carpal pad touches the ground when standing
 B. Treatment
 1. Splinting is not usually successful because there are soft tissue injuries present with little support for the carpus
 2. Arthrodesis is the treatment of choice. If the antebrachiocarpal joint can be preserved, there will be little gait alteration after surgery

3. If plates are used, splint for 6 to 8 weeks post surgery. Once soft tissue swelling has subsided, the splint can be changed to a cast if necessary

C. Postoperative complication
1. Soft tissue swelling is common for a few days post surgery. Monitor the tightness of the bandage and splint
2. Complications are rare once bony fusion has occurred

FRACTURES OF THE PELVIS

I. Causes
A. Very common
B. Severe trauma (e.g., hit by car) is usually the cause
C. Concurrent injuries are common

II. Anatomy
A. Major weight-bearing regions are the sacroiliac joint, body of the ilium, and acetabulum
B. Each half of the pelvis is composed of the ilium, ischium, pubis, and acetabulum

III. Diagnosis
A. Determine whether there are other concurrent injuries. Treat shock, perform radiographs (especially of the chest), perform an electrocardiogram, make sure that the urinary tract is intact. Caudal abdominal hernias can occur in conjunction with pelvic fractures
B. When the patient is stable, radiograph the pelvis to evaluate bony injury. Perform a neurologic examination to evaluate spinal reflexes, anal tone, and perineal sensation

IV. Treatment
A. Malunions are common. Repair fractures as soon as the patient is stable and are a good anesthetic risk
B. Nonsurgical treatment
1. Used for unilateral fractures, fractures with minimal displacement, fractures of the non–weight-bearing portion of the pelvis. Nonsurgical treatment is best in animals with intact neurologic function and no soft tissue injuries that require surgery
2. Nursing care can be extensive. Many are reluctant to stand or turn over. A padded bed should be used; turn the patient regularly, and keep the patient clean and dry
3. Provide pain control
4. Prevent constipation with stool softeners or mild laxatives
5. Empty the urinary bladder regularly
6. Restrict activity to cage rest for 3 to 4 weeks
7. Physical therapy will help lessen disuse atrophy
C. Surgical treatment indications
1. Fracture of the ilium with fracture of the pubis and ischium that creates an unstable acetabulum
2. Fractures of the acetabulum
3. Displaced or unstable sacroiliac fractures
4. Severe bilateral fractures of the pelvis
5. Pelvic fracture associated with hip luxation or femoral fracture
6. Fractures of the ischium that entrap the sciatic nerve
7. Fracture of the pubis with herniation
8. Gross displacement of the iliac crest or ischiatic tuberosity

V. Special considerations
A. Fractures of the ilium
1. Damage to the sciatic nerve may be present
2. Surgical repair is usually recommended because most are displaced or unstable, and the ilium is weight bearing
3. Plates and screws are usually used
4. Seroma formation is common. Use warm compresses to treat
5. Restrict activity to leash walks for 6 to 8 weeks
6. The prognosis is good with good stabilization
B. Fractures of the acetabulum
1. Usually accompanied by other pelvic fractures
2. These are difficult fractures to repair; the surgical approach is difficult, and rigid fixation is necessary
3. The treatment of choice is surgical stabilization
4. Femoral head and neck ostectomy can be performed if it is not possible to reconstruct an acetabular fracture
5. Restrict activity to leash walks for 6 to 8 weeks
6. If there is good stabilization, prognosis is good. If stabilization is poor, the prognosis is fair to poor; OA usually develops. If femoral head ostectomy is performed, the prognosis is guarded to fair
C. Sacroiliac fracture or luxation
1. Surgical treatment is difficult, so manage nonsurgically if possible
2. Perform neurologic examination and evaluate bladder function, anal tone, and perineal sensation
3. If neurologic deficits are present, the prognosis is guarded
D. Fractures of the ischium
1. Usually associated with fractures of other weight-bearing regions of the pelvis
2. Surgical repair is usually unnecessary unless there is severe pain or displacement that impacts function of the hip
E. Fractures of the pubis
1. More common in young animals in which the pelvic symphysis has not yet fused
2. Surgery is usually unnecessary unless there is herniation of abdominal or pelvic organs
F. Narrowed pelvic canal associated with healed pelvic fractures
1. Obstipation and dystocia are most common in cats and small dogs
2. Subtotal colectomy may be necessary if there is obstipation

DISORDERS OF THE COXOFEMORAL JOINT

I. Anatomy
 A. Ball-and-socket joint made up of the acetabulum and femoral head
 B. The fossa of the acetabulum and the fovea of the femoral head may be mistaken for radiographic abnormalities
 C. The femoral head has an extensive blood supply
 D. The major muscles of the thigh all have insertions or origins close to this joint

II. Coxofemoral luxation
 A. Diagnosis
 1. Animals will usually not bear weight on the limb
 2. If you pull the hindlimbs directly caudally, they should be the same length in a normal animal. If they are different lengths, the coxofemoral joint is most likely dislocated
 B. Closed reduction
 1. Replace the femoral head into the acetabulum with the patient under general anesthesia using rotation and traction
 2. Once the hip is back in place, use a flexion sling if the luxation was craniodorsal; use hobbles if the luxation was caudoventral. Restrict motion for 7 to 14 days, depending on the age of the animal. Limit exercise for an additional 2 to 4 weeks (Figure 22-3)
 3. Reluxation is not uncommon. If reluxation occurs, use an open reduction
 C. Open reduction
 1. If there is an avulsion fracture, surgery should be performed
 2. The typical approaches are the cranial lateral approach to the hip or the trochanteric osteotomy approach
 3. Reduce the femoral head, and then anchor it to prevent relaxation
 4. Reluxation is not uncommon. If this occurs then excision arthroplasty or total hip replacement is considered
 5. Restrict activity for 1 month

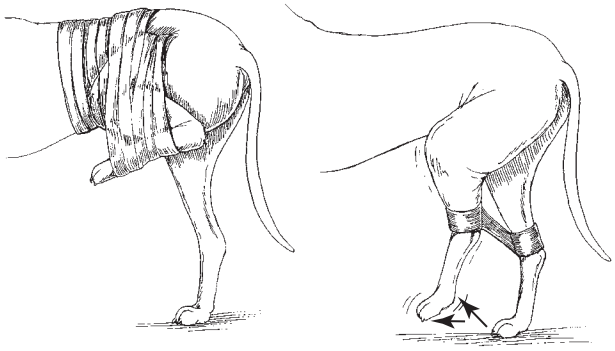


Figure 22-3 After reduction, use a flexion (Ehmer) sling for a craniodorsal luxation (left) and hobbles for a caudoventral luxation (right). (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

III. Avascular necrosis of the femoral head
 A. Causes
 1. Also known as Legg-Perthes or Legg-Calve-Perthes disease
 2. Most common in young small-breed dogs
 3. No history of trauma; lameness is bilateral in about 15% of animals
 4. Cause is unknown
 5. Weight bearing causes the bone to collapse with fracture of the cartilage
 B. Diagnosis
 1. Diagnosis is based on physical examination and radiographs
 2. Limb may be shortened and muscles atrophied
 3. On radiographs, decreased bone density is noted, with a widened joint space
 C. Treatment
 1. Surgery is usually necessary
 2. Excision arthroplasty (removal of the femoral head and neck) is the most common procedure because dogs with such injury are usually small

IV. Hip dysplasia
 A. Causes
 1. The most common disorder of the hip in the dog and the most common cause of OA
 2. Most commonly affects large- and giant-breed dogs, although all breeds can be affected
 3. There is a polygenic mode of inheritance
 4. Joint instability results as the stresses at the hip joint exceed the support of the surrounding soft tissues
 B. Diagnosis
 1. Lameness and gait abnormalities are usually seen, especially after exercise
 2. Ortolani sign: Place a hand on the knee and apply dorsal pressure to the femur while moving the leg from an adducted to an abducted position. If a click is heard, this is a positive Ortolani sign and indicates joint laxity
 3. Radiographic findings range from subluxation of the femoral head to severe secondary DJD
 C. Treatment
 1. Medical treatment involves weight control, alleviation of pain, reduction of inflammation, and restriction of activity
 2. Surgery is considered when medical management is no longer effective
 3. Surgical procedures
 a. Triple pelvic osteotomy: Used in patients with little evidence of DJD. Osteotomies of the ilium, pubis, and ischium are performed, and the acetabulum is rotated so that it provides more coverage of the femoral head. Restrict activity for 8 weeks
 b. Femoral head and neck excision arthroplasty: This is a salvage procedure used in smaller dogs (i.e., less than 40 lb). The femoral head and neck are removed, which removes the painful contact points in the joint. Encourage use of the limb within 1 week of surgery. It will take 2 to 3 months for the limb to reach a functional level. There may be muscle atrophy or a post-legged gait

c. Pectineal myectomy: The entire pectineus muscle is removed, which decreases tension on the medial aspect of the coxofemoral joint capsule and may relieve some of the associated pain. Restrict activity for 2 weeks. Seroma formation is common
d. Total hip replacement: Growth plates must be closed. Performed in dogs weighing more than about 40 lb. Strict asepsis must be adhered to, and the dog must be free of infection. Restrict activity for 2 months. About 95% of dogs will have satisfactory function

FRACTURES OF THE FEMUR

I. Proximal femur
 A. The proximal femur includes the femoral head, the femoral neck, the trochanters, and their attachments to the femoral shaft. The sciatic nerve runs caudal to the hip on top of the gemelli, internal obturator, and quadratus femoris muscles. The femoral artery, nerve, and vein are very superficial in the femoral triangle
 B. Preoperatively, stabilize the patient, take radiographs, and administer antibiotics
 C. The most common approach is the craniolateral approach. Fractures can be repaired, or a femoral head and neck ostectomy can be performed
 D. The proximal femur is subject to many stresses, and stability can be a problem. Prevent weight bearing for the first few weeks, then start non-weight-bearing physical therapy after that. Repeat radiographs before initiating significant activity
 E. There will be a period of increased vascularity and decreased bone density of the femoral neck postoperatively. Monitor with serial radiographs
II. Femoral diaphysis
 A. The femoral artery and nerve pass medially down the length of the shaft. The sciatic nerve is located caudal to the vastus lateralis muscle and lateral to the semimembranosus muscle
 B. Preoperatively, stabilize the patient, take radiographs, and administer antibiotics
 C. A combination of intramedullary pins and cerclage wires are typically used for fixation. If the fracture is highly comminuted, external fixation will probably be necessary to provide stability
 D. Maintain soft tissue attachments to bone fragments. Use avascular bone fragments only if they are needed to obtain stability
 E. If the fracture repair is stable, start leash walks 3 to 5 days after fixation, and increase activity slowly over 4 weeks. Remove implants if needed about 6 to 8 weeks after repair
 F. Healing may fail if stability is not good or osteomyelitis occurs. Nonstable, devitalized bone fragments can lead to draining tracts. Excessive periosteal reaction with large callus formation may occur
III. Distal femur
 A. Includes the metaphysis, condyles, trochlea, and patella. The femoral artery divides into the popliteus and saphenous arteries, which run laterally and medially on the caudal aspect of the distal femur. The peroneal and saphenous nerves run caudal to the femur
 B. Evaluate for ligament injuries to the stifle
 C. Most of the fractures are physeal fractures
 D. Lateral, medial, or cranial approaches can be used. Pins, plates, or screws may be chosen for fixation
 E. Restrict activity for at least 24 hours; if the fixation is stable, start leash walks 1 to 2 days after surgery
 F. Contracture of the quadriceps can occur from adhesions, usually when the leg is fixed in an extended position. DJD can result if the fixation is not stable. In young animals, there may be limb shortening from physeal closure

ORTHOPEDIC DISORDERS OF THE STIFLE

I. Anatomy
 A. Patella luxation, cruciate disruptions, and meniscal problems account for about 95% of stifle disorders in dogs and cats
 B. The cranial stifle is made up of the quadriceps muscles, patella, patellar tendon, and tibial tuberosity, aligned with the coxofemoral joint, talocrural joint, and paw. There should be no medial or lateral deviation
 C. Neurovascular structures run longitudinally and close to the caudal joint capsule
II. General preoperative considerations
 A. Do a complete orthopedic evaluation
 1. Palpate the patellar tendon. If the edges feel indistinct, this indicates stifle effusion which is associated with cranial cruciate rupture or DJD secondary to rupture
 2. Determine range of motion of the stifle. Clicks may be heard that indicate crepitus and meniscal pathology
 3. Attempt cranial movement of the tibia while holding the femur motionless (the drawer sign or Lachman test). Movement indicates laxity of the cranial cruciate ligament
 4. With the femur held motionless, grasp the hock and rotate the tibia. Normally there is 20 to 30 degrees of internal rotation, with 5 to 10 degrees of external rotation
 5. Exert medial and lateral digital pressure on the patella while moving the stifle to detect patellar luxation
 6. Exert pressure on the lateral side and medial side to detect increased laxity of the joint space and laxity of the collateral ligaments
 7. Exert deep pressure on the stifle to determine focal pain
 B. Obtain radiographs
III. Principles of stifle surgery
 A. Place dog in dorsal recumbency
 B. Perform an arthrotomy to identify and examine all structures
IV. Patellar luxation
 A. Commonly affects miniature breeds. Medial patellar luxations are most common; lateral luxations almost always occur in large and giant breeds

B. Generally congenital or developmental. Contributing factors include decrease or increase in the angle formed by the head and neck of the femurs, bowing of the distal part of the femur, a shallow trochlear groove, increased internal or external tibial rotation, and malpositioned tibial tuberosity
C. Classification of luxations
1. Grade I: The patella lies in the trochlear groove but can be manually subluxated or luxated
2. Grade II: There is clinical spontaneous luxation; the patella can be luxated manually but reduces spontaneously or with minimal manipulation
3. Grade III: The patella is luxated most of the time but can be reduced manually
4. Grade IV: Patellar luxation cannot be reduced manually
D. Diagnosis is based on a history of intermittent rear-leg lameness, particularly during exercise
E. Surgical procedures vary; some require parapatellar arthrotomy and release to diminish the tension on tissue, and some require arthrotomy with tightening of surrounding tissues
F. The objective is to stabilize the patella and maintain a full range of motion
G. Surgical techniques
1. Trochleoplasty: Deepening of the trochlear groove. Begin physical therapy on the day of surgery; restrict activity for 1 month
2. Chondroplasty: Used in dogs less than 6 months of age
3. Wedge resection: Remove a piece of the trochlea, then cut a piece below to deepen, and replace the first removed wedge
4. Imbrication: After creating increased depth in the trochlear groove, perform imbrication (tightening) of the lax side using either the DeAngelis technique or Flo technique
5. Tibial tuberosity translocation

V. Cranial cruciate ligament rupture
A. There is usually an acute onset of rear-limb lameness, usually during exercise. Chronic lameness may be present in older overweight dogs. There is firm swelling on the medial aspect of the joint with a chronic cruciate ligament rupture
B. The cranial drawer sign will be present with rupture of the cranial cruciate ligament
C. Tibial compression: Use one hand to hold the femur motionless with a finger resting on the tibial tuberosity, then gently dorsiflex the hock with the other hand. If cranial cruciate ligament laxity is present, the tibia will move cranially. The cranial drawer test is more consistent than the tibial compression test
D. Surgical techniques are classified as either intracapsular (stabilization from within the joint) or extracapsular (stabilization outside the joint)
1. Intracapsular techniques: Patellar tendon techniques, over-the-top repairs, and under-and-over repairs
2. Extracapsular techniques: Lateral imbrication technique, and tibial plateau leveling osteotomy (TPLO)
E. Fascial strip over-the-top technique: Suitable for dogs that weigh less than 40 lb
F. Lateral retinacular imbrication technique: Most common extracapsular technique; can be performed on any size patient
G. TPLO: This procedure is gaining in popularity. It is designed to eliminate tibial thrust where the tibia moves forward during active weight bearing in the stifle with cranial cruciate ligament laxity. The tibial plateau is leveled to nearly perpendicular to the long axis of the tibia. An intact caudal cruciate ligament is required. It is probably best suited for large or giant breeds or very active dogs. TPLO requires specialized equipment and expertise
H. Postoperative care
1. Administer analgesics
2. Padded bandage for 1 to 2 days to reduce swelling
3. With a fascial strip, use a lateral splint, leash walk for 3 months, return to normal function after 6 to 9 months
4. With lateral retinacular imbrication, limit exercise for 6 weeks, and gradually return to normal activity over the next 2 to 4 weeks
5. With TPLO, limit exercise for 8 weeks, then radiograph to assess bone healing

VI. Caudal cruciate ligament rupture
A. Extremely rare. There is acute lameness and a caudal drawer sign with 90 degrees of stifle flexion
B. Avulsion of the bony attachment is also present

VII. Meniscal problems
A. Isolated meniscal tears are rare in dogs. Meniscal pathology is usually associated with partial or complete cranial cruciate tear
B. With cruciate injury, there is craniocaudal and rotational laxity, which allows the femoral condyles to traumatize the caudal horn of the medial meniscus
C. Diagnosed by hearing or palpating a click during range of motion
D. Surgery indicated to remove or repair the menisci

VIII. Collateral ligament disruptions
A. Occur as a result of severe varus (medial) or valgus (lateral) stress to the stifle
B. Classification
1. First degree: Stretching and minor disruption of collagen fibers; responds to rest and restricted exercise
2. Second degree: Partial tearing; responds to rest and restricted exercise
3. Third degree: Complete discontinuity of the ligament; requires surgical repair
C. The objective is to restore the integrity of the injured ligament and stability of the stifle

IX. Stifle luxation
A. Severe trauma is necessary for stifle luxation to occur. It is more common in cats. The patellar tendon is usually not disrupted
B. Repair ligaments and tendons to reestablish joint stability
C. Place an external fixator, setting pins in the distal femur and proximal tibia, and maintain for 3 to 4 weeks. Alternative to external fixation is to use a full cast. Place the stifle in a partially flexed position

FRACTURES OF THE TIBIA AND FIBULA

I. Introduction
 A. Account for about 15% to 20% of long bone fractures in small animals
 B. There is minimal soft tissue coverage of these bones, so fractures are often open
II. Anatomy
 A. Epiphysis: The epiphyseal regions are composed of loosely woven, trabecular bone, which limits the holding power of fixation implants. Epiphyseal regions serve as ligament and tendon insertions and are subjected to tensile forces. Epiphyseal regions that support articular cartilage are subjected to compressive loads. Fracture healing in this area is rapid due to the ample blood supply
 B. Physis: This region exists only in young, growing animals. Injuries here can cause premature cessation of growth
 C. Metaphysis: This is an indistinct region between the physis and diaphysis
 D. Diaphysis: The tibial diaphysis is subjected to bending and torsional forces. Fractures here heal slowly and require prolonged rigid fixation
III. Preoperative considerations
 A. Evaluate cardiopulmonary function and neurologic function. Look for other musculoskeletal injuries
 B. Provide antibiotics if the fracture is open
IV. Surgical procedures
 A. Pin and tension band wire fixation: Used for avulsion fractures of the fibular head, tibial tubercle, or lateral or medial malleolus
 B. Interfragmentary lag screw fixation: Used for intra-articular fractures of the proximal and distal epiphysis and for reconstruction of comminuted shaft fractures prior to plating
 C. Cross pin and rush pin fixation: Used for transverse fractures of the epiphysis, axially stable fractures of the metaphysis, and Salter I and II fractures of the proximal and distal physis
 D. Intramedullary pin and wire fixation
 1. Used for simple, axially stable fractures of the tibial diaphysis
 2. Contraindicated in infected or contaminated open fractures, or in fractures that cannot be reconstructed
 3. The pin should be about 50% to 60% of the smallest medullary canal diameter
 4. Cerclage wires can be used on long oblique fracture line, which can be accurately reduced
 5. Interfragmentary wires can be used to stabilize short oblique patterns
 E. External skeletal fixation
 1. Indicated in stable reducible and nonreducible fracture patterns, open fractures with significant soft tissue damage, or infected fractures
 2. Contraindicated in intra-articular fractures and avulsion fractures of ligament and tendon epiphyseal attachments
 3. External fixation is usually placed on the medial side of the tibia
 F. Plate and screw fixation: Indicated when the stabilized limb is needed for immediate weight bearing because of injury to other limbs, restricted activity is not possible, and rigid fixation is necessary
V. Postoperative care and complications
 A. Apply compressive wrap for 3 to 5 days to prevent soft tissue swelling
 B. Cover connecting bars and clamps of external fixation with tape and gauze
 C. Do not routinely remove small pins, wires, screws, but remove large intramedullary pins
 D. Remove plates if chronic infection and drainage occur, if animal experiences pain when exposed to cold ambient temperatures, or when the plate design induces bone atrophy
 E. Complications include nonunion, malunion, infection, and growth deformities
 F. Infection requires immediate aggressive therapy to avoid progression to osteomyelitis and nonunion

LUXATION, SUBLUXATION, AND SHEARING INJURIES OF THE TARSAL JOINT

I. Anatomy
 A. The tarsus consists of the tibia, fibula, metatarsal bones, and seven tarsal bones
 B. The tarsocrural joint is between the tibia and fibula proximally and the talus and calcaneus distally
 1. Most luxations and subluxations involve this joint
 2. The major ligaments for stability on the medial side are the long medial ligaments and tibiotalar short component ligament
 3. The major ligaments for stability on the lateral side are the long lateral ligament and the calcaneofibular short component ligament
 C. The intertarsal joints are between the tarsal bones. The most common injury is damage to the plantar ligaments and tarsal fibrocartilage
II. Tarsocrural luxation and subluxation
 A. Surgery is recommended
 B. Luxation results from combinations of injuries that fracture the malleoli and damage contralateral ligaments
 C. Subluxation occurs from rupture or avulsion of either the lateral or medial collateral ligament complexes
 1. With a medial rupture, the paw tilts laterally with a lateral valgus force
 2. With a lateral rupture, the paw tilts medially with a medial varus force
 D. Perform radiographs to check for other injuries
 E. Double-prosthesis replacement
 1. Reproduces the components of the medial and lateral collateral ligament, allowing joint stability to be maintained
 2. Double-ligament replacement yields better results than conservative management
 3. After surgery, allow some weight-bearing mobilization using a soft cast. Make sure the hock is in a functional standing angle. Maintain the cast for 4 to 12 weeks. Once the cast has been removed, slowly increase activity over the next 4 to 12 weeks

III. Shear injury
 A. The medial side is injured more often than the lateral side
 B. Joint arthrodesis is considered if extensive bone and cartilage damage is present
 C. Objectives of surgery are to prevent infection, stabilize the tarsocrural joint, eliminate pain, and maintain a functional range of motion
 D. Perform debridement as soon as possible. Irrigate with copious amounts of fluids
 E. Replace ligaments at this time, or do this later if repeated debridement is necessary. Ligaments are replaced with bone anchors or screws and figure-eight sutures
 F. Stabilize with a rigid splint; change dressing daily
 G. Postoperative care
 1. Firmly immobilize the tarsocrural joint until there is granulation tissue or the wound is sutured. Avoid using external skeletal fixator as this is detrimental to the joint. A rod incorporated into a wrap can be used
 2. After the rigid external fixation has been removed, semi-immobilize the hock for another 6 to 12 weeks. Then slowly increase the activity level over another 8 to 16 weeks
 3. The prognosis is good if there is no damage to articular surfaces other than the malleolus
IV. Tarsocrural joint arthrodesis
 A. Indications include moderate to severe osteochondral damage, prolonged tarsocrural joint subluxation or luxation causing DJD, or failure of reconstructive surgery
 B. Fuse the tarsocrural, intertarsal, and tarsometatarsal joints, and fuse the hock at a functional angle
V. Intertarsal luxation and subluxation injuries
 A. Often occur as a part of daily activity with no known trauma. Jumping can damage plantar ligaments and cause hyperextension injury
 B. Usually non–weight–bearing, with possible swelling
 C. Hyperextension injuries are treated by arthrodesis or tension band wire stabilization
VI. Proximal intertarsal subluxation with plantar instability
 A. Injury results from excessive dorsiflexion; the animal walks plantigrade
 B. Usually occurs with no known trauma
 C. Does not respond to conservative management with splints. Treat surgically with arthrodesis of the calcaneoquartal joint
 D. After surgery, provide a soft-cast splint for 4 to 8 weeks and restrict activity until there is bony fusion
VII. Proximal intertarsal luxation with plantar instability
 A. Occurs infrequently compared with subluxation injuries
 B. Trauma results in a hyperextension injury
 C. Perform arthrodesis of the intertarsal joint with a bone plate
 D. After surgery, provide a soft-cast splint. Remove when there is evidence of bony fusion. Remove the plate after arthrodesis is complete
VIII. Distal intertarsal (tarsometatarsal) subluxation with plantar instability
 A. Less common than proximal subluxation injury
 B. Usually associated with trauma
 C. Treat with arthrodesis of the distal intertarsal joint
 D. After surgery, provide a soft-cast splint; remove when there is evidence of bony fusion
IX. Intertarsal-tarsometatarsal subluxation injuries
 A. Proximal intertarsal subluxations
 1. No evidence of trauma
 2. Periodic lameness is present
 3. Treat with rigid splints
 B. Distal intertarsal subluxation. Valgus deformity is seen. Stabilize with tension band wire
 C. Tarsometatarsal subluxation. Stabilize with medially positioned tension band if there is dorsomedial instability; if there is dorsal instability, manage with rigid splints
 D. Luxation of talus, central tarsal bone, talocalcaneus. Treat with surgical fixation

ORTHOPEDIC DISORDERS OF THE DISTAL EXTREMITIES

I. Introduction
 A. Usually result from direct trauma
 B. Most involve the metacarpal and metatarsal bones
 C. Acute, non–weight-bearing lameness is common
II. Metacarpal and metatarsal fractures
 A. Body fractures may involve multiple bones
 B. Closed reduction is usually effective, but surgery may be necessary if displacement or multiple bone fragments are seen
 C. For surgical fixation, intramedullary pins can be used. A single pin will not provide rotational stability. Plates or lag screws can also be used for fixation
 D. External splinting is used to augment internal fixation
III. Base and head fractures
 A. Usually involve the second and fifth metacarpals. Avulsion fractures are common
 B. Surgical fixation is recommended. With base fractures, fix with lag screws. With head fractures use Kirschner and cerclage wires. Use supplementary splinting for about 4 weeks
 C. Remove intramedullary pins following bone union. If the patient is a working dog, then also remove plates
 D. Limit exercise for about 10 weeks
 E. Rarely, delayed union or nonunion results
IV. Phalangeal fractures.
 A. Most are treated without surgery, and fiberglass splints are used
 B. Surgery is indicated if the patient is a large working dog or racing dog, if there is an articular fracture involving the base or head, or if external splinting has failed. Procedures are similar to metacarpal and metatarsal fractures
V. Palmar and plantar sesamoid injuries
 A. Usually seen in racing greyhounds but can affect any dog, especially large-breed dogs

B. Signs include sudden lameness with swelling and pain
C. There are eight sesamoid bones, and fractures of the second and seventh are most common
D. Most acute injuries are treated externally. If there is recurrent lameness then surgery is recommended
E. External treatment involves a snug padded bandage on the paw for 7 to 10 days, with limited exercise for 2 weeks

AMPUTATION OF THE DIGIT

I. Onychectomy (cats)
 A. Preoperative considerations
 1. Young cats recover more quickly than do older cats
 2. Most cats should be kept indoors after onychectomy because they will have a reduced ability for defense or escape
 B. Surgery
 1. Completely remove the claw and ungual crest to prevent claw regrowth
 2. Place a tourniquet below the elbow
 3. Remove the claw using either a scalpel or guillotine nail trimmers. A carbon dioxide laser can also be used
 4. Incisions can be left open or can be closed with a single absorbable suture or tissue glue
 5. Apply snug-fitting bandages before removing the tourniquet
 C. Postoperative Care
 1. Bleeding is occasionally a problem
 2. Infection is uncommon
 3. Cats should be kept indoors, and shredded paper should be used for the litter box
 4. Regrowth of a deformed nail can occur from incomplete removal of the ungual crest
II. Dewclaw removal (dogs)
 A. Usually performed in the neonate
 B. In neonates, remove with a scissors, and control bleeding with pressure or silver nitrate. The incision may be left open or closed with a single absorbable suture. No bandage is necessary
 C. In older animals, the skin should be closed and bandaged
 D. Remember that some dog breeds are required to have dewclaws present if they are being shown in conformation competition. Some breeds also have double dewclaws that must remain intact for the show ring
III. Digit removal (dogs and cats)
 A. Usually removed because of severe trauma, osteomyelitis, or neoplasia
 B. It is preferable to maintain the digital pad if possible
 C. The primary weight-bearing digits are the third and fourth digits
 D. Apply a tourniquet below the elbow, remove the digit using a scalpel or bone cutters, close the incision, and bandage for 7 to 10 days
 E. Dehiscence or tumor regrowth are complications of surgery

SURGERY OF SKELETAL MUSCLE AND TENDONS

I. Introduction
 A. Common
 B. Scar tissue must be kept to a minimum to regain proper function
II. Anatomy
 A. Muscles are encased in thick connective tissue called *epimysium*. *Perimysium* carries blood vessels and nerves, and binds myofibers into groups to form fasciculi. *Endomysium* is connective tissue in between muscle fibers
 B. *Tendons* are long bands of collagen fibers arranged in parallel rows. The *fibroblast* is the cellular component. *Endotenon* is loose connective tissue that surrounds the collagen fibers. *Epitenon* covers the entire tendon and is continuous with the endotenon on the undersurface. The *paratenon* is the outer sheath of the tendon, which separates tendons from each other, and forms a synovial membrane in areas of local pressure. *Vascular* tendons are surrounded by soft tissue, and *avascular* tendons are surrounded by a tendon sheath, which may lead to poor healing
III. Healing of muscle
 A. Classification system for muscle injury
 1. Grade I: Tearing of a few muscle fibers with intact muscle fascia and minimal hemorrhage
 2. Grade II: More severe than grade I, with hematoma formation
 3. Grade III: Tearing of a large amount of muscle, torn fascia, diffuse hemorrhage
 4. Grade IV: Complete rupture of one or more muscle bellies
 B. Vascular supply is important for healing. Scar tissue increases if there is a poor source of healing myoblasts, poor vascularization or innervation, and excessive stress on the wound. Large areas that cannot revascularize quickly will form scar tissue rapidly
 C. Prolonged immobilization will decrease scar formation, but it also causes irregular orientation of muscle fibers that will decrease the tensile strength. Excess stress across a wound will increase scar formation, but some motion across the wound promotes proper parallel orientation of regenerating muscle fibers. However, it may also produce excessive granulation tissue formation. Thus there is a balance between providing necessary motion across a wound and providing too much or too little motion
IV. Healing of tendon
 A. Direct apposition of tissues provides optimal tendon healing
 B. Steroid injections around tendons cause substantial tendon weakening for 2 weeks, with weakening for more than a year. Hyperadrenocorticism can cause tendon weakening and tearing
V. Diagnosis of muscle and tendon injury
 A. Muscle ruptures can be palpated, and there may be bruising or a hematoma at the site
 B. With tendons, there may be increased laxity of the involved joint

VI. Surgery of skeletal muscle
 A. Preserve blood supply, use gentle handling, create a tension-free anastomosis, and remove excessive scar tissue to provide accurate apposition of the muscle ends
 B. Muscle holds suture poorly, so take large bites of tissue and use the dense, outer fascial layer to minimize sutures pulling through. Use horizontal mattress or cruciate suture patterns
 C. Immobilize the limb for 2 to 3 weeks, then gradually return to activity over the next 4 weeks
VII. Surgery of tendons
 A. Remove hematomas and scar tissue
 B. Locking loop pattern is useful for flat tendons. More than one locking loop can be used to increase tensile strength
 C. The three-loop pulley suture pattern is used for round tendons. The three-loop pulley suture pattern provides more tensile strength than does the locking loop
 D. Provide drainage if there is excessive dead space
 E. Provide rigid immobilization using a cast or external fixators for 4 to 6 weeks. Then allow gradual return to function over another 4 weeks

NEOPLASIA OF THORACIC AND PELVIC LIMBS

I. Introduction
 A. Primary bone tumors usually affect middle-aged to older animals, although younger dogs can be affected
 B. Primary bone tumors are usually in the metaphysis, only in one bone, and do not cross a joint space
 C. Metastatic bone tumors can occur anywhere in the bone and affect multiple bones. Tumors that metastasize to bone are usually epithelial origin
II. Primary skeletal neoplasms
 A. Osteosarcoma (OSA)
 1. Most are in the appendicular skeleton. The distal radius is the most common site for OSA. Other common sites include the proximal humerus, distal femur, and proximal tibia. In small-breed dogs, the proximal humerus may be the most common site
 2. OSAs are typically aggressive and originate in the metaphysis of long bones
 3. Large-and giant-breed dogs are more likely to be affected with OSA
 4. Metastatic lung disease is a common sequelae
 5. OSA is less aggressive in cats. The hindlimb is more commonly affected in cats
 6. Long-term prognosis is poor. With chemotherapy, about 45% survive 1 year. Without chemotherapy, only 10% of dogs survive 1 year. Poor prognostic indicators in dogs include a preoperative alkaline phosphatase greater than 110 μ/L, OSA in a young dog, a high tumor grade, and pulmonary metastasis
 B. Chondrosarcoma
 1. Chondrosarcoma is the second most common tumor in the appendicular skeleton
 2. Medium- to large-breed dogs are more commonly affected
 3. Surgical resection is associated with increased survival (unlike OSA)
 4. Prognosis is still poor, with only 30% surviving at 1 year with treatment
 C. Fibrosarcoma and hemangiosarcoma are the third and fourth most common tumors in the appendicular skeleton
 D. Other less common primary tumors include osteoma, chondroma, osteochondroma, enchondroma, malignant mesenchymoma, liposarcoma, plasma cell myeloma, lymphosarcoma, and giant cell tumor
III. Primary soft tissue neoplasms
 A. Synovial cell sarcoma
 1. Tumor arises from the joint capsule
 2. Most common in middle-aged to older animals
 3. The stifle and elbow are the most common areas affected
 4. Radiographs show an osteolytic pattern associated with a joint. The tumor typically crosses the joint space
 5. Tumors with a higher biologic grade are more likely to metastasize
 6. Recurrence is common, so amputation is recommended for local tumor control
 B. Other soft tissue neoplasms include hemangiosarcoma, rhabdomyosarcoma, lymphosarcoma, fibrosarcoma, and malignant histiocytosis. The sarcomas usually require biopsy for diagnosis
IV. Metastatic neoplasia
 A. Carcinomas are most likely to metastasize to bone. Prostatic carcinoma, transitional cell carcinoma of the bladder, and mammary carcinomas tend to metastasize to bone
 B. Tumors are usually seen in the diaphysis, whereas primary bone tumors are typically in the metaphysis
 C. Biopsy is important for diagnosis
V. Clinical signs
 A. Signs range from subtle lameness to acute non–weight-bearing lameness with pathologic fractures through affected bone
 B. Respiratory signs may be noted if pulmonary metastasis is present
VI. Diagnosis
 A. On radiographs, cortical lysis, periosteal reaction, and bony proliferation strongly suggest neoplasia. Check lungs for metastasis
 B. Definitive diagnosis is by biopsy. Also aspirate regional lymph nodes
VII. Treatment
 A. Surgery
 1. Most require amputation of the affected limb. Amputation is not indicated in patients that will have difficulty with only three limbs (overweight patients, those with other orthopedic diseases in the remaining limbs)
 2. Amputation should be performed at least one joint above the affected bone. Amputation involves loss of a large amount of fluid and blood. Administer antibiotics

3. Radiation therapy or chemotherapy or both are usually performed in conjunction with surgery
4. Lung metastases can be surgically removed but only if there are no more than two visible pulmonary nodules, there is metastasis only to the lung, and the primary tumor has been in remission for about 9 months

B. Chemotherapy
1. Chemotherapy increases survival rate over that of amputation alone
2. Cisplatin and carboplatin are used
3. Myelosuppression and nephrotoxicity are side effects of cisplatin therapy. Carboplatin is less nephrotoxic but might not be as effective
4. Chemotherapy is started when the skin sutures are removed

C. Radiation therapy
1. Radiation therapy can help relieve pain of primary and metastatic bone neoplasia
2. Sarcomas may develop in a previously irradiated site

VIII. Limb amputation
A. Thoracic limb amputation
1. It is easier to remove both the scapula and humerus than just to remove the humerus
2. It is easiest to do a mid-humerus amputation; but with subsequent atrophy of the muscles, the humerus and scapula become very prominent, which is cosmetically not pleasing to most owners
3. Know the anatomy of the area, ligate all major vessels, and close as much dead space as possible. Provide drainage if necessary

B. Pelvic limb amputation
1. Can be amputated at the mid-femur level if the tumor does not involve the femur or stifle
2. Amputation is by hip disarticulation if there is femur involvement
3. If the tumor involves the proximal femur, this may require removal of the acetabulum and part of the pelvis
4. Know the anatomy of the area, ligate all major vessels, and close as much dead space as possible. Provide draining as necessary

IX. Postoperative care and complications
A. Provide pain control
B. Seroma formation can be managed with pressure bandages and warm compresses or drain placement
C. Provide nursing care until the patient is able to ambulate on three limbs
D. Start chemotherapy after the skin sutures have been removed
E. Watch for tumor recurrence (radiograph every 2 to 3 months)
F. Maintain a normal body weight

MISCELLANEOUS DISEASES OF BONE

I. Panosteitis
A. Causes
1. Affects young large-breed dogs
2. Cause is unknown, but there may be a genetic component, as German shepherd dogs are commonly affected
3. Causes may include stress, vascular abnormalities, metabolic disorders, allergies, hyperestrogenism, or autoimmune reaction following a viral infection
4. On histopathology, there is a degeneration of medullary adipocytes, with stromal cell proliferation, intramembranous ossification, and regeneration of the adipose bone marrow

B. Clinical signs
1. Usually seen in large- and giant-breed dogs up to 1 year of age; it may occur up to middle-age
2. Male dogs are more frequently affected than females (4:1). In females it is often associated with the first estrus
3. There is acute weight-bearing lameness with no history of trauma. Clinical signs continue for several months and resolve by about 18 months of age

C. Diagnosis
1. Pain can be elicited by firm palpation of a long bone
2. Radiographs show areas of increased density and accentuated trabecular pattern within the medullary cavity. Cortices may be thickened. There is no correlation between radiographic lesions and clinical signs
3. Differentials include hypertrophic osteodystrophy (HOD), osteochondritis dissecans, ununited anconeal process (UAP), and hip dysplasia

D. Treatment
1. Panosteitis is self-limiting
2. Administer NSAIDs, and restrict exercise if severely affected

II. Hypertrophic osteodystrophy (HOD)
A. Causes
1. Unknown; it does not appear to be due to a vitamin C deficiency
2. Canine distemper virus may be involved

B. Clinical signs
1. Usually occurs in young, rapidly growing large- and giant-breed dogs; signs start at about 3 to 4 months of age
2. Clinical signs are episodic; lameness is usually bilateral; and anorexia, weight loss, fever and depression may be observed in severe cases. Lameness can be mild to non–weight-bearing
3. Affected long-bone metaphyses are swollen, warm, and painful; multiple bones can be affected

C. Diagnosis
1. Often based on history and physical examination
2. Radiographs show generalized sclerosis and enlargement of the metaphysis. Widening of the physis may be seen in later stages; subperiosteal or extraperiosteal bone formation may also be seen. Radiolucent areas form in the metaphysis and form an area of radiolucency parallel to the growth plate (a double physeal line)

3. Differentials include panosteitis, neoplasia, and hypertrophic osteopathy (HO)

D. Treatment
1. If mild, regression is often spontaneous
2. Decreasing caloric intake may be helpful
3. Supportive care may be necessary. If severely affected, these animals may need to be force-fed or have a feeding tube placed
4. Administer NSAIDs as needed

III. Hypertrophic osteopathy (HO)

A. Causes
1. Occurs secondary to other diseases, most commonly to metastatic pulmonary neoplasia
2. Has occurred in association with primary pulmonary tumors, pulmonary abscesses, bronchopneumonia, heartworms, spirocercosis, rib tumors, endocarditis, hepatic adenocarcinoma, and bladder neoplasms
3. The pathogenesis is unknown but may relate to the increased peripheral vascular supply secondary to pulmonary lesions

B. Clinical signs
1. Any breed of dog or cat can be affected; animals can be any age
2. May be more common in females and large-breed dogs because of the higher incidence of mammary tumor metastases and primary bone tumors in large-breed dogs
3. Most present with acute or gradual lameness of all four limbs

C. Diagnosis
1. Distal limbs are swollen, warm, and painful
2. Radiographs show bilateral, symmetric, periosteal proliferative reaction affecting the long bone. Endosteal bone proliferation does not occur. Distal portions are involved first
3. If the primary disease resolves, the radiographic abnormalities regress

D. Treatment
1. Resect primary or metastatic pulmonary neoplasms
2. Treat heartworms, spirocercosis, or primary lung disease
3. Clinical signs resolve a few weeks after removal of the thoracic or abdominal mass. Periosteal reactions regress in 3 to 4 months. Lameness may persist
4. Unilateral vagotomy may be helpful if the primary mass cannot be removed

IV. Craniomandibular osteopathy

A. Cause
1. Probably heritable; likely autosomal recessive
2. Osteoclastic resorption of mandibular bone occurs, followed by production of woven bone
3. Most common in the mandibles but also in occipital bones or temporal bones

B. Clinical signs
1. Onset is at 4 to 10 months of age; both sexes are affected equally
2. Signs include pain on manipulation of the mouth, mandibular swelling, ptyalism, intermittent fever, and lethargy

C. Diagnosis
1. Pain occurs when trying to open the mouth
2. Radiographs show bilaterally symmetric bony proliferation projecting from the periosteal surfaces of the mandible or other bones of the cranium. The angular processes of the mandible may fuse and restrict movement
3. Lesions are static by about 1 year of age. There may be partial or complete regression of bony lesions
4. Prognosis is poor if the TMJ has fused
5. Differentials include HOD

D. Treatment
1. Administer NSAIDs, and provide nutritional support with a gastrostomy or enterostomy tube
2. Surgical treatment has had limited success

V. Multiple cartilaginous exostosis (MCE)

A. Cause
1. Probably heritable
2. The exostosis is derived from displaced chondrocytes that separate from the physis

B. Clinical signs
1. There is a firm swelling on a bone
2. Lameness occurs only if the bony swelling compresses tendons or nerves

C. Diagnosis
1. A smooth, nonmovable bony swelling is visible near the metaphysis
2. These growths may involve any bone except the skull

D. Treatment
1. Removal improves the appearance, and there are reports of malignant transformation to chondrosarcomas or OSAs
2. Prognosis is good after removal

VI. Bone cysts

A. Cause
1. Unknown
2. There are four types of bone cysts: *Monostotic* (affects one bone), *polyostotic* (affects multiple bones), *aneurysmal*, and *subchondral*. The aneurysmal type is rare but aggressive. Subchondral cysts may be the result of chronic OA

B. Clinical signs
1. Most animals are less than 1 year old
2. Reported in the German shepherd dog, Weimaraner, Irish wolfhound, Afghan hound, saluki, Great Dane, and Doberman pinscher
3. Pain, swelling, stiffness, or acute lameness may be present

C. Diagnosis
1. Radiographs show an expansive, radiolucent area in the metaphysis. The cortex may be thinned, and fractures may be present
2. Differentials include chondrosarcoma, OSA, and giant cell tumors

D. Treatment
1. Curettage and fill the defect with cancellous bone
2. Cysts can be resected if they are in flat bones
3. Treat fractures through cysts with fracture fixation

VII. Retained endochondral cartilaginous cores
 A. Cause unknown
 B. Clinical signs
 1. Occurs in the distal ulnar metaphysis of young large-breed dogs
 2. Signs include valgus deviation, external rotation of the carpus, and cranial bowing of the radius
 C. Diagnosis
 1. Radiographs show a central, longitudinal radiolucent cone in the distal ulnar metaphysis
 2. This is usually an incidental finding
 D. Treatment is not necessary if there is no deformity

VIII. Labrador retriever skeletal dysplasia
 A. Cause
 1. Heritable with autosomal recessive transmission
 2. Recognized only in Labrador retrievers
 B. Clinical signs
 1. Forelimbs appear short and exhibit achondroplastic conformation. This is noted at about 2 to 4 months of age
 2. There is also abnormal conformation of the coxofemoral joints
 3. Ocular changes are present and include cataracts, retinal dysplasia, and retinal detachments
 C. Diagnosis
 1. History, clinical signs, and physical examination are diagnostic
 2. Radiographs demonstrate the asynchronous growth of the radius and ulna
 D. There is no treatment. Monitor breeding lines and remove probable carriers from a breeding program

OSTEOCHONDROSIS

I. Etiology
 A. Osteochondrosis refers to the failure of an endochondral ossification
 B. Osteochondritis dessicans (OCD) refers to the combination of articular cartilage lesions and synovitis from communication of synovial fluid into subchondral bone. Usually affects large-to giant-breed dogs

II. OCD of the shoulder, hock, and stifle
 A. Pathophysiology
 1. Focal retention of cartilage due to a defect in endochondral ossification
 2. Joint mouse formation occurs
 B. Clinical signs
 1. Shoulder
 a. Usually in large-breed dogs, 4 to 8 months old; males predisposed
 b. Unilateral or bilateral
 c. Lameness after exercise; pain with shoulder extension
 2. Hock
 a. Usually in large-breed dogs, 5 to 8 months old; rottweilers, Labradors, and bullmastiff predisposed
 b. Hindlimb lameness with shortened stride and hyperextension of the tarsocrural joint
 3. Stifle: Large-breed dogs, 5 to 7 months old, with mild to severe hindlimb lameness
 C. Diagnosis
 1. High-quality, well-positioned radiographs are needed
 2. The lesion appears as a flattened or saucer-like "divot" in the subchondral bone
 D. Preoperative considerations
 1. Patients with small lesions and minimal OA will have the best results
 2. Dogs with OCD of the hock might not need surgery
 E. Surgical procedures: Use arthrotomy or arthroscopy; debride to the level of subchondral bleeding bone
 F. Postoperative care: Leash walks for 6 weeks followed by gradual return to function over the next 6 weeks
 G. Prognosis
 1. Prognosis for OCD of the shoulder is good to excellent
 2. Prognosis for OCD of the hock is poor unless treatment has been initiated early
 3. Prognosis of OCD of the stifle is fair

III. Canine elbow dysplasia
 A. Pathophysiology: Elbow dysplasia is a collection of disorders, including UAP, fragmentation of the medial coronoid process, or OCD of the medial portion of the humeral condyle (Figure 22-4)
 B. Ununited anconeal process (UAP)
 1. Anatomy: UAP is failure of the anconeal process to fuse with the ulna by 20 to 24 weeks of age
 2. Pathophysiology: May be secondary to an abnormal size or shape of the trochlear notch
 3. Clinical signs
 a. Usually affects large-breed dogs
 b. Forelimb lameness with external rotation of the foot by 5 to 8 months of age
 4. Diagnosis: On flexed lateral radiograph, an irregular radiolucent line is seen between the anconeal process and the olecranon
 5. Surgical procedures
 a. Remove the anconeal process
 b. Approach is via a caudolateral arthrotomy
 6. Postoperative care and complications
 a. Leash walks for 6 weeks post surgery
 b. Gradual return to normal activity over the next 6 weeks
 7. Prognosis is fair to good. Many are lame later in life because of OA. Prognosis can be excellent if the anconeal process fuses after surgery
 C. OCD of the medial portion of the humeral condyle and fragmentation of the medial portion of the coronoid process (FMCP) of the ulna
 1. Pathophysiology
 a. FMCP: OCD may play a role, or a long ulna with short radius precipitates fragmentation
 b. OCD: Failure of endochondral ossification

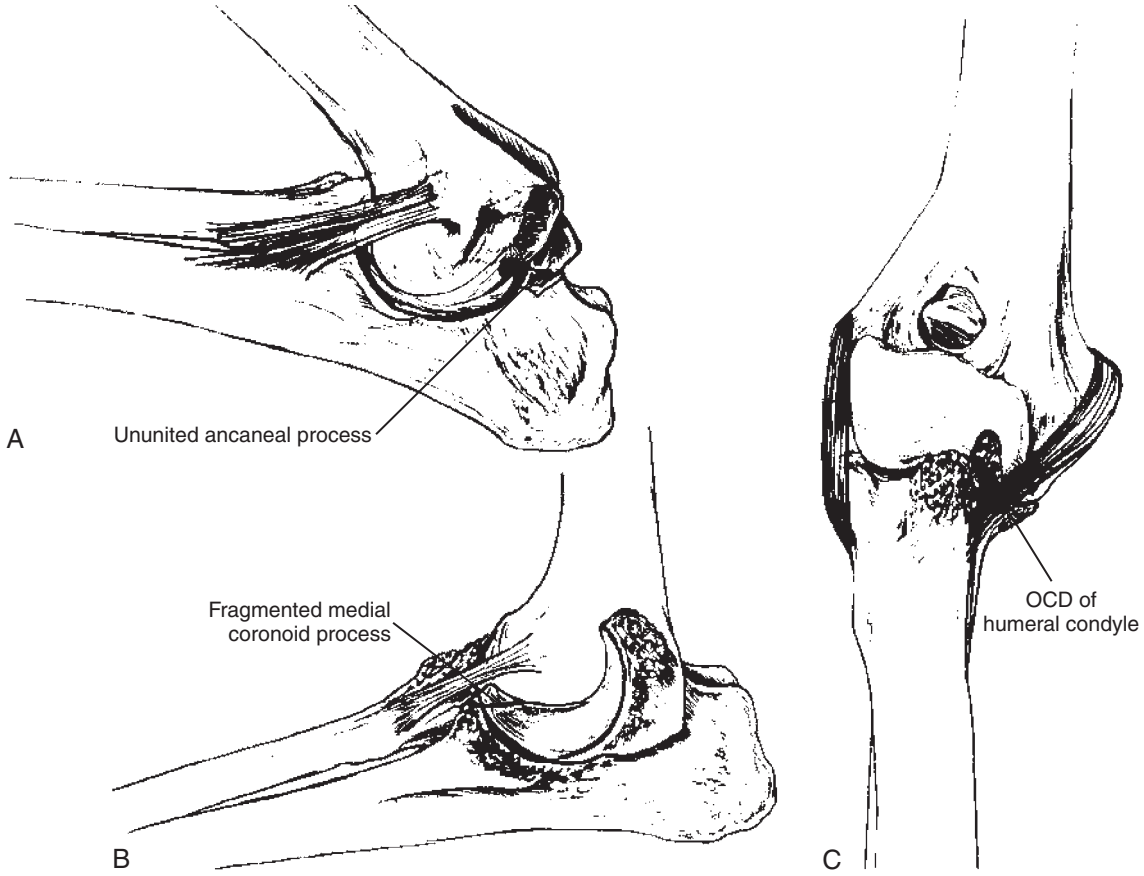


Figure 22-4 The various manifestations of elbow dysplasia include **(A)** ununited anconeal process (UAP), **(B)** fragmentation of the medial portion of the coronoid process (FMCP) of the ulna, and **(C)** osteochondritis dessicans (OCD) of the medial portion of the humeral condyle. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

2. Clinical signs
 a. Forelimb lameness at about 5 to 7 months of age
 b. Lameness is worse after exercise
 c. Lameness is usually unilateral
 d. Pain with flexion and extension of the joint is evident
3. Diagnosis
 a. FMCP: Radiographic findings are nonspecific; diagnosis is often based on the presence of OA
 b. OCD: A triangular subchondral bone defect is seen in the medial portion of the humeral condyle
4. Differential diagnosis includes UAP, OCD of the shoulder, and panosteitis
5. Treatment
 a. Medical management involves weight loss, exercise moderation, treatment with NSAIDs and chondroprotective agents
 b. Preoperative considerations
 (1) Surgery does not stop DJD progression
 (2) Persistent lameness and mild DJD are indications for surgery
 c. Surgical procedure
 (1) FMCP: Remove the fragments and debride
 (2) OCD: Debride to the level of subchondral bleeding bone
6. Postoperative care and complications
 a. Strict restriction of exercise for 4 to 6 weeks
 b. Long-term medical management of OA
7. Prognosis is guarded because of DJD. Most dogs have intermittent lameness

PEDIATRIC FRACTURES

I. Cause
 A. Commonly seen because immature bone is weaker
 B. Most common site is in the metaphyseal region; 30% of fractures involve the metaphyseal growth plate
II. Anatomy
 A. Immature long bone consists of the *diaphysis* (the compact shaft), the *metaphysis* (the intermediate zone), and the *epiphysis* (the terminal portion). The metaphysis is the weakest of the three. The physis is between the epiphysis and metaphysis and is the area responsible for longitudinal growth
 B. Blood vessels do not cross the physis, so the metaphysis and epiphysis have separate blood flow. The periosteum also has an extensive blood supply

C. Histology of the physis: The physis is composed of five developmental zones. From epiphysis to metaphysis, the zones are the reserve zone, the proliferative zone, the hypertrophic zone, the ossification zone, and the metaphyseal zone
 1. The reserve zone is important for storing nutrients and germinal cells
 2. The proliferative zone is the growth zone where chondrocytes rapidly divide and form palisades
 3. The hypertrophic zone is where chondrocytes enlarge by accumulation of fluid and calcium
 4. Chondrocytes begin to degenerate in the ossification zone, and deposit calcium into the matrix
 5. Remodeling of the primary and secondary spongiosa occurs in the metaphyseal zone

III. Classification of physeal fractures (Figure 22-5)
 A. Type I fractures: Characterized by separation of the epiphysis from the metaphysis through the physis
 B. Type II fractures: Fracture through portions of the physis and metaphysis
 C. Type III fractures: Occur through the physis and epiphysis (intra-articular)
 D. Type IV fractures: Occur through the metaphysis and epiphysis (intra-articular)
 E. Type V fractures: Crushing injuries that involve all zones of the physis
 F. Type VI fractures: Physis is injured resulting in peripheral closure of one side of the physis

IV. Preoperative considerations
 A. Immature bone is soft and easily fractured with manipulation
 B. Immature bone heals very quickly due to rapid bone turnover
 C. Gentle tissue handling and preservation of blood supply are important
 D. Fractures with an intra-articular component require surgical repair

V. Surgical repair: Small Kirschner wires, pins, or screws will provide stabilization with the least amount of physical trauma

VI. Postoperative care
 A. Eliminate high-impact activity
 B. If using casts or bandages, re-evaluate weekly because large breeds may quickly outgrow the cast
 C. Physical therapy will help minimize callus formation, muscle atrophy, and joint contracture

VII. Complications
 A. Exuberant bony callus is a problem in unstable fixations
 B. Bony callus can cause fusion between bones and cause angular limb deformity
 C. Premature physeal closure can also cause angular limb deformity
 D. Limb shortening may result from premature physeal closure

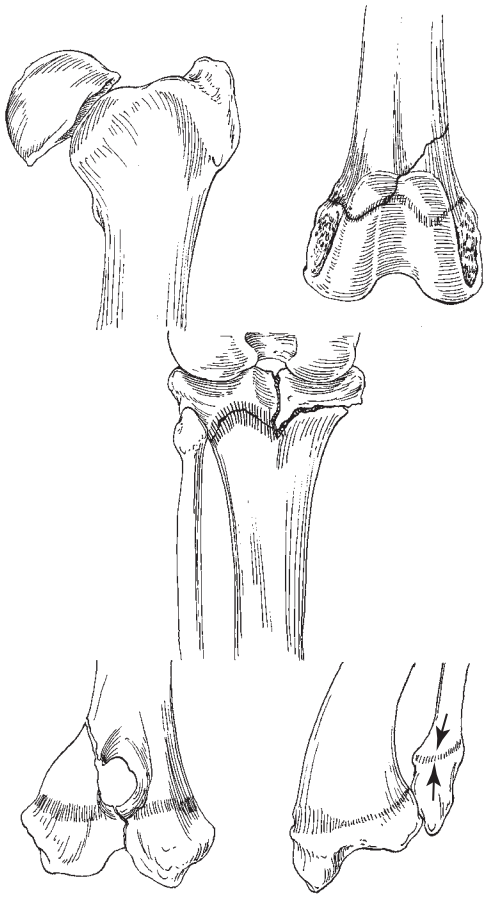


Figure 22-5 Five different types of growth plate fractures. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders .

OPEN FRACTURES

I. Classification: Open fractures have been exposed to the environment and contaminated by or infected with bacteria
 A. Type I
 1. Fracture fragment penetrates the skin, exposing the fracture to bacteria
 2. Soft tissue injury is minor; wound infection is unlikely
 B. Type II
 1. An external object penetrates the skin and soft tissues, fractures the bone, and contaminates the wound
 2. Soft tissue injury is usually minimal, but bacterial contamination is more extensive than in type I injuries
 C. Type III
 1. An external object penetrates the skin and soft tissues, creates a fracture, contaminates the wound, and severely damages the soft tissues
 2. Typically there is vascular compromise and necrosis. The risk of bacterial infection is very high

II. Preoperative considerations
 A. Strict asepsis should be followed during wound management. Cover all wounds with sterile dressing, and use aseptic techniques when manipulating the wounds
 B. Stabilize the fracture temporarily if definitive treatment is delayed

C. Culture the wound for definitive antibiotic treatment
D. Give broad-spectrum antibiotics while waiting for results of the culture

III. Fracture fixation and soft tissue reconstruction
A. Objectives are to provide fracture fixation, reduce the risk of infection, and reconstruct soft tissue to cover bone
B. Debridement
1. Type I
a. Little surgical debridement is necessary
b. Lavage the wound with sterile lactated Ringer's solution if bone is not visibly exposed
c. Excise necrotic tissue before fracture fixation
2. Type II
a. Surgical debridement is not extensive, but make sure to remove necrotic tissue
b. Copiously lavage the wound before fixation
3. Type III
a. Use aseptic technique to prepare and drape
b. Remove necrotic tissue and loose fragments of bone
c. Preserve the blood supply; maintain tissue attachments to bone fragments
d. Clean tendons, ligaments
C. Fixation
1. Type I: Repair with the appropriate method of fixation; close routinely. Drains are usually not necessary
2. Type II: Repair with the appropriate method of fixation; provide proper drainage or use delayed wound closure
3. Type III: Do not use intramedullary pins because of the difficulty in providing adequate drainage. Use external fixation if possible
D. Reconstructive soft tissue surgery
1. Wounds may be left to heal by second intention. Some wounds might not heal
2. Skin grafts or flaps can be constructed at the time of fixation but can be delayed until infection is resolved

IV. Postoperative care
A. Analgesics
B. Elizabethan collar
C. Keep bandaged; lavage daily
D. Restrict activity
E. Radiographs; postoperative physical therapy

V. Complications
A. Continued infection from necrotic tissue or bone, or instability
B. Delayed healing from prolonged infection, poor reduction, instability, or bone loss

OSTEOMYELITIS

I. Cause
A. Bacteria
1. Chronic bacterial osteomyelitis is the most common form
2. β-lactamase-producing *Staphylococcus aureus* causes most infections. Other common bacteria include *Pseudomonas, Escherichia coli, Streptococcus, Bacteroides, Actinomyces,* and *Clostridium* spp.
B. Fungal
1. Fungi usually enter through the respiratory tract and spread via blood. Most fungal infections are in the vertebral bodies or bones of the skull
2. Caused by *Coccidioides, Blastomyces, Histoplasma, Cryptococcus*, or *Aspergillus* spp.

II. Diagnosis
A. History includes previous orthopedic surgery, trauma, chronic dental disease, injury to the toes, or travel to endemic fungal regions
B. Physical examination
1. Clinical signs include lameness, inappetence, malaise, fever, muscle atrophy, and pain on palpation
2. Swelling, heat, pain, or draining tracts may be seen with digital osteomyelitis
3. With disseminated fungal infections, there may be mucopurulent nasal discharge, coughing, or pulmonary crackles or wheezes
C. Hematology may show neutrophilic leukocytosis, but there may not be any abnormalities
D. Diagnostic imaging
1. Osteomyelitis will not be evident until after 10 to 14 days on survey radiographs. May see focal bone lucencies and aggressive periosteal proliferation
2. Contrast radiography may be useful
E. Laboratory evaluation
1. Obtain samples for culture (bacterial and fungal)
2. Smears may be useful for diagnosing fungal infections

III. Treatment
A. Objectives are to identify pathogens, drain infected tissues, remove avascular bone, stabilize fractures, or to implant bone grafts to aid union of fractures
B. Acute osteomyelitis
1. Antibiotics should be administered after obtaining appropriate samples. For oral administration, use amoxicillin-clavulanate or enrofloxacin. For parenteral use, ampicillin with amikacin or enrofloxacin can be used
2. Acute osteomyelitis is painful, so consider injectable narcotics
3. Provide rigid fracture fixation
4. If wounds are left open, cover with sterile bandages, and lavage daily
5. Continue with appropriate antibiotics
C. Chronic osteomyelitis
1. Amputation should be considered if there is neurologic damage, considerable muscle contracture, soft tissue loss, or financial constraints
2. Provide good stabilization of the fracture. Irrigate, and use bone grafts to fill in bone defects
3. Use appropriate antibiotics based on culture results for 4 to 6 weeks
4. Radiograph at 3- to 6-week intervals to assess healing
5. Consider physiotherapy or swimming to maintain range of motion

DELAYED UNION, NONUNION, AND MALUNION

I. Definitions
 A. *Delayed union* refers to a fracture that requires longer than usual to heal but shows progression of healing. Radiographs show callus formation and progressive bone healing
 B. *Nonunion* refers to a fracture that does not heal and shows no sign of healing
 C. Malunion refers to the faulty union of a fracture.
II. Causes of nonunion
 A. Usually inadequate fracture fixation, resulting in instability. It is more common in transverse fractures, where stability is harder to attain
 B. If the fracture gap is too wide, this will exceed the regenerative capacity of bone, resulting in nonunion
 C. In miniature and toy breeds, there is limited blood supply to the distal radius, so fractures in this location have a higher incidence of nonunion
III. Histology
 A. With delayed union or nonunion, there is increased periosteal cartilage in the callus
 B. Gaps at bone ends are filled with fibrous tissue
 C. With nonunions, chondroid tissue, areas of degeneration with necrosis, and fibrous connective tissue are seen
 D. Sclerosis at the ends of bone may seal the medullary cavity
IV. Clinical signs
 A. Lameness which may be non–weight-bearing
 B. Pain, joint stiffness, muscle atrophy, infection, or noted movement of the fracture may occur
V. Diagnosis
 A. Delayed union: Radiographs show progressive callus formation and resorption of dead bone; the marrow cavity remains open
 B. Nonunion: Radiographs show no progression of fracture healing (over a 3-month period), with smooth fracture surfaces, and evidence of sclerosis at bone ends. Bone fragments may be noted
 C. Radiographs may show lucency around a screw or wire, indicating that it is loose
VI. Surgery for nonunion
 A. Prepare at least one cancellous graft donor site
 B. Administer antibiotics
 C. Obtain tissue from the surgery site for culture and sensitivity
 D. Improve stability of the fracture site, and place an autogenous cancellous graft
 E. Rigid stability is best achieved with plates and screws
 F. If there is apparent infection, consider open would management
 G. Aggressive physical therapy is needed. Perform passive range of motion exercises starting immediately after surgery. Encourage short walks or swimming and controlled weight bearing
 H. The prognosis depends on compromise of joint function resulting from scar tissue, nerve function, and limb angulation
VII. Malunion
 A. Malunions occur as a result of untreated or improperly treated fractures
 B. Signs include angular deformities, shortening of the limb, and soft tissue adhesions. There may be decreased range of motion, or DJD
 C. Deformities can be treated surgically. Limbs are straightened using corrective osteotomy. Provide stable fixation
 D. Postoperative care is the same as for any fracture fixation. Complications include decreased range of motion, limb shortening, infection, or undercorrection or overcorrection of the deformity

OSTEOARTHRITIS

I. Introduction
 A. OA describes pathologic process of cartilage degeneration
 B. Osteoarthrosis stresses the noninflammatory nature of this disease
 C. DJD encompasses all the changes seen in OA
 D. OA is seen more frequently in dogs than in cats
II. Anatomy and physiology
 A. Diarthrodial joints consist of articular cartilage lubricated by synovial fluid secreted by synovial membrane lining. The synovial membrane contains pain receptors
 B. Articular cartilage is 80% water, with type II collagen and proteoglycan matrix, which is synthesized by chondrocytes. Normal cartilage chondrocytes continually synthesize and degrade proteoglycan
 C. Proteoglycan consists of repeating chains of glycosaminoglycans (chondroitin sulfate and keratin sulfate [GAGs]). GAGs are bound to a protein core, which is bound to hyaluronic acid to form aggrecan. The negative charges of GAG prevent compression during a compressive load, which allows it to deform and reform with repetitive loads
III. Causes
 A. Can be caused by primary or secondary disorders, but secondary disorders are much more common
 B. Secondary causes of OA include OCD, hip dysplasia, cranial cruciate ligament injury, patellar luxation, joint instability, and malunion of intra-articular fractures
IV. Pathophysiology
 A. Cartilage abnormalities include increased synthesis and degradation of proteoglycan, increased cartilage hydration, loss of collagen integrity, loss of tensile strength, fibrillation, and eburnation
 B. Synovial membrane abnormalities include synovitis from mononuclear cell infiltration with increased inflammatory mediators within the synovial fluid
 C. Interleukin-1 (IL-1) and tumor necrosis factor-α (TNF-α) promote degradative cartilage enzyme production. Insulin-like growth factor, transforming growth factor-α, and IL-6 are associated with increased proteoglycan synthesis

D. Even though there is increased proteoglycan synthesis with OA, the destruction and loss of proteoglycan from the matrix are greater

V. Clinical signs
A. Morning stiffness that improves with gentle exercise
B. Lameness is worse after heavy exercise. Lameness may be in one or more legs

VI. Diagnosis
A. Reduced range of motion and joint effusion suggest OA
B. Any age or breed can be affected. There may be a history of previous trauma
C. Palpate for pain, crepitus, and joint laxity
D. Radiographic abnormalities include joint effusion, osteophytes, subchondral bone sclerosis, and bone remodeling
E. Joint fluid analysis is rarely needed. Joint fluid analysis yields a noninflammatory, mononuclear cell population

VII. Treatment
A. Medical treatment
1. Nonsteroidal antiinfl ammatory drugs (NSAIDs)
a. NSAIDs reduce prostaglandin production, decrease pain and inflammation
b. Most NSAIDs also reduce proteoglycan synthesis, which worsens the pathology of OA
c. Nephrotoxicity and gastric toxicity are side effects of NSAID use. Use the lowest possible dose to minimize gastric and renal side effects and to minimize cartilage damage
d. COX-1 (cyclo-oxygenase 1) inhibitors lead to gastric ulceration and nephrotoxicity. COX-2 is induced by cytokines, so COX-2 inhibitors are better for treatment
2. NSAIDS for use in all dogs
a. Buffered aspirin works better than nonbuffered aspirin. Aspirin should be used with extreme caution in cats. Aspirin may cause gastrointestinal (GI) side effects (ulceration). Aspirin is primarily a COX-1 inhibitor
b. Carprofen may be the first choice over aspirin because there is less chance of GI side effects. Carprofen is related to ibuprofen but has less COX-1 inhibition than COX 2 inhibition compared with ibuprofen
c. Deracoxib has selective COX- 2 inhibition. It is licensed for dogs only
d. Etodolac has selective COX- 2 inhibition and undergoes extensive enterohepatic recirculation
e. Meloxicam has selective COX- 2 inhibition and is licensed for use in dogs
f. Phenylbutazone is licensed for use in small animals but should not be used in cats. Phenylbutazone may cause GI irritation and bone marrow suppression
3. NSAIDS for use in dogs in which surgery is not an option
a. Piroxicam is very effective for pain relief. It is not licensed for use in small animals, and gastric ulceration may occur. It may not depress proteoglycan synthesis as much as other NSAIDs
b. Meclofenamic acid is effective for pain relief and is licensed for dogs. GI side effects occur
c. Ibuprofen should not be used because of its side effects
d. Corticosteroids severely decrease synthesis of proteoglycans and should be used only for very short-term therapy (several weeks). Steroids should be avoided in patients undergoing surgery
4. Chondroprotective agents
a. Polysulfated glycosaminoglycans may be especially helpful in hip dysplasia. In the past, they were administered intra-articularly but are now given intramuscularly
b. Glucosamines have not been thoroughly evaluated but may have benefit. The idea is that by oral supplementation of glucosamine, more proteoglycan will be produced
c. Shark cartilage supplement has anecdotal benefit with minimal side effects
d. Vitamin C has questionable benefit but has no side effects
e. Tramadol is an opioid analgesic that provides good pain relief
B. Surgical treatment
1. Surgery should be considered in OCD, cranial cruciate ligament disease, patellar luxation, and hip dysplasia
2. Surgery will slow the progression of OA and improve lameness

IMMUNE-MEDIATED ARTHRITIS

I. Cause
A. The cause is unknown, but IL-1 and TNF-α may play a role in the pathology
B. The initial site of pathology is in the synovium, unlike OA, where the initial site is the articular cartilage
C. Nonerosive forms
1. Characterized by antigen-antibody deposition in the synovium (type III hypersensitivity)
2. These complexes stimulate inflammatory mediator release. The inflammatory process releases metalloproteinases (a cartilage-degrading enzyme), which leads to more synovial inflammation and cartilage degradation. When these complexes involve antinuclear antibodies, this is termed systemic lupus erythematosus (SLE)
D. Erosive forms
1. Rheumatoid arthritis is an erosive form. Host immunglobulin G (IgG) becomes antigenic, with rheumatoid factor (immunglobulin M [IgM]) being formed in response
2. Binding of IgG with IgM triggers inflammatory mediator release. Articular cartilage erosion results

II. Clinical signs
A. Canine nonerosive arthritis
1. Affects large-breed, middle-aged dogs
2. Signs may be acute, with lameness, fever, lethargy, and swelling, especially of distal joints

3. Nonerosive arthritis is more commonly seen and is classified into four groups
 a. Type I: An idiopathic cause; accounts for about 50% of small animal cases
 b. Type II: Associated with remote infection from sites other than joints. Joints are not infected; arthritis is caused by immune complexes that have deposited in the joint. Accounts for 25% of small animal cases
 c. Type III: Associated with chronic GI disease; accounts for 15% of small animal cases
 d. Type IV: Associated with neoplasia remote to joints; accounts for 10% of small animal cases

B. Nonerosive arthritis syndromes
 1. Systemic lupus erythematosus (SLE)
 a. Autoimmunity to body tissues. Immune complexes involve antinuclear antibodies
 b. Problems include thrombocytopenia, glomerulonephritis, hemolytic anemia, neutropenia, dermatitis, and polyarthritis
 2. Juvenile-onset polyarthritis syndrome in Akitas
 a. Affects Akitas under 1 year of age
 b. Clinical signs include cyclic pain, fever, lymphadenopathy, and meningitis
 3. Inflammatory arthritis of Chinese shar-peis
 a. Affects any age
 b. Associated with episodic fever and swelling of the hocks. Usually associated with renal amyloidosis
 4. Polyarthritis-polymyositis
 a. Affects spaniels
 b. Signs include muscle pain, atrophy, muscle contracture, fever, and polyarthropathy. Serum creatine kinase is usually elevated
 5. Polyarthritis-meningitis
 a. Affects Bernese mountain dogs, beagles, boxers, German shorthaired pointer, and Weimaraners
 b. Signs include cyclic fever and neck pain for 3 to 7 days. Joint swelling may be seen
 6. Idiopathic drug-induced polyarthritis
 a. Secondary to sulfonamide administration but can occur after administration of other antibiotics
 b. Doberman pinschers are most susceptible

C. Canine erosive arthritis
 1. Rheumatoid arthritis
 a. Most common canine erosive arthritis but less common than nonerosive arthropathies
 b. Affects smaller-breed dogs of any age
 c. Signs include fever, lethargy, swollen joints, and shifting leg lameness. Angular deformities may occur
 2. Greyhound polyarthritis
 a. Affects young greyhounds. *Mycoplasma spumans* is a suspected cause
 b. Signs include acute onset of joint swelling, fever, weight loss, pneumonia, and diarrhea

D. Inflammatory arthropathies of cats
 1. Nonerosive forms
 a. Types I to IV as in dogs also occur in cats
 b. When polyarthropathy is present, bone marrow neoplasia should be suspected. This is usually due to lymphoma or multiple myeloma
 c. Feline progressive polyarthritis may be both nonerosive or erosive. The nonerosive form is more common and occurs almost always in male cats. Signs include stiffness, fever, and lymphadenopathy. Feline syncytia-forming virus and feline leukemia virus have been implicated as a cause
 2. Erosive forms are not common; chronic onset of stiffness of the carpi or tarsi is seen

III. Diagnosis
 A. History and physical examination
 1. Perform a thorough physical examination; peripheral lymphadenopathy and splenomegaly may be present
 2. About 30% of dogs with nonerosive form have dermatitis or focal alopecia
 3. Fever may be present
 B. Radiography
 1. Nonerosive forms show joint swelling and minimal osteophytes
 2. Erosive forms show small or large lytic areas on subchondral bone and osteophytosis
 C. Laboratory evaluation
 1. Inflammatory leukogram and hyperglobulinemia suggests inflammation
 2. In nonerosive forms, more than 50% of patients are proteinuric, so hypoalbuminemia may be present
 3. Rheumatoid factor test: False-positives and false-negatives occur. Positive in about 75% of cases
 4. Antinuclear antibody: usually positive in SLE
 D. Joint fluid analysis: Predominant cell type is usually nondegenerate neutrophils; mononuclear cells are sometimes predominant
 E. Synovial biopsy: Histology shows plasma cell and lymphocyte infiltration

IV. Treatment
 A. Nonerosive forms: Treated with NSAIDs or corticosteroids (but not both). Treat for 2 to 4 months. Recurrences are possible; if there are repeated recurrences, treat long-term with the lowest dose of steroid possible
 B. Erosive forms usually require immunosuppression with cyclophosphamide along with prednisone. Stop cyclophosphamide after 4 months of therapy. Azathioprine can be used instead of cyclophosphamide in dogs only. Gold sodium thiomalate can be used to maintain remission
 C. Surgery is usually not used for treatment
 D. Supportive care includes weight control and exercise restriction

V. Prognosis
 A. Nonerosive forms
 1. Prognosis for types I, II, and III is favorable; prognosis for type IV is guarded

2. Prognosis depends on the breed and specific condition

B. Erosive forms
 1. Difficult to treat and can be expensive
 2. Greyhound polyarthritis and erosive feline progressive polyarthritis have poor prognosis

Supplemental Reading

Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, Chapters 96-124.

Piermetti DL, Flo GL, DeCamp CE. *Brinker, Piermattei and Flo's Handbook of Small Animal Orthopedics and Fracture Repair*, 4th ed. St Louis, 2006, Saunders.

23 CHAPTER

Preventive Medicine

Valerie A. Chadwick

VACCINATIONS

I. Vaccinations are an important part of preventative medical practices, thus providing animals with optimum health care
 A. Vaccination itself is a potent medical procedure associated with known benefits and risks. Knowledge of these benefits and risks is necessary to implement an effective individualized vaccination protocol
 B. Considerations of exposure, susceptibility, severity of disease, efficacy and safety of the vaccine, potential public health concerns, and owner's preferences are appropriate

II. Vaccinations have contributed greatly to the well-being of our companion animals. The number of patients with infectious disease has decreased appreciably since the first vaccines were available

III. Recommendations for vaccines had been considered a routine part of animal care
 A. Differences in risk exposure to infectious diseases, age and health of the patient, and potential side effects make it difficult to recommend one protocol for all dogs or cats
 B. An annual wellness examination should be recommended even if the vaccinations are not being given in a particular year for the overall continued health of the animal

IV. Puppies under 16 weeks of age represent the most susceptible age group
 A. They experience the highest rates and most severe cases of disease and therefore the principal target population for vaccination
 B. Because of maternal antibody influences, a series of periodically spaced vaccinations is indicated in young dogs

V. Feline vaccination protocols
 A. The American Association of Feline Practitioners and Academy of Feline Medicine created an advisory panel in 1997 to develop guidelines for vaccination of cats. These guidelines were adopted by the Vaccine-Associated Feline Sarcoma Task Force for administration of vaccines
 B. Vaccines containing antigens limited to Rhinotracheitis-Calicivirus-Chlamydia-Panleukopenia (RCCP) are administered subcutaneously on the right shoulder
 C. A vaccine containing rabies virus antigen (plus any other antigen) is administered on the right hindlimb as distally as possible
 D. Vaccines containing feline leukemia (with or without any other antigen except rabies) are administered on the left hindlimb as distally as possible

VI. Core vs. noncore vaccination
 A. *Core vaccines* are defined as vaccines appropriate to protect most animals against diseases that pose a risk of severe disease due to virulent, highly infectious pathogens, as well as being highly distributed
 B. Noncore vaccinations target diseases of minimal risk in the geographic region or lifestyle of the pet and protect against diseases that are less severe threats to infected animals. Noncore vaccines should be considered on an individual basis
 C. Core vaccines
 1. Canine: Core vaccines considered for dogs are distemper, parvovirus, adenovirus-2, and rabies
 2. Feline: Vaccines against panleukopenia, rhinotracheitis, and calicivirus should be considered core vaccines for cats. Vaccines against feline leukemia virus should be considered a core vaccine if the cat spends time outdoors or has interaction with outside cats
 D. Noncore vaccines
 1. Canine: Noncore vaccines considered for the dog are parainfluenza, *Bordetella*, coronavirus, Lyme disease, and *Giardia.* Leptospirosis may be considered either core or noncore, depending on the area of the country the dog is living in and exposure risk
 2. Feline: Noncore vaccines to consider for the cat are chlamydiosis, feline infectious peritonitis, *Microsporum canis*, bordetellosis, giardia, and feline immunodeficiency virus (FIV)

VII. Veterinarians should provide their clients with adequate information regarding vaccine choices so owners can make an informed decision regarding vaccinations for their animals. Currently a signed consent for administered vaccines is not required, but this may change with time (Table 23-1)

HEARTWORM AND FLEA PREVENTATIVES

I. Heartworm preventatives (Table 23-2)
 A. Heartworm preventatives kill backwards in time
 1. Ivermectin, milbemycin oxime, moxidectin, and selamectin kill L3 and L4 up to 60 days back in time

Table 23-1 Canine and Feline Vaccinations

Canine Vaccine	Initial Puppy Vaccination	Initial Adult Dog Vaccination	Revaccination	Comments
Canine distemper virus (MLV)	Administer 6-8 wk of age, then every 3-4 wk until 12-14 wk old	Two doses 3-4 wk apart	One year booster at 15 mo then revaccination once every 3 yr considered protective	Core
Canine distemper virus (rCDV)	Administer 6-8 wk of age, then every 3-4 wk until 12-14 wk old	Two doses 3-4 wk apart	One year booster at 15 mo, then revaccination once every 3 yr considered protective	Core
Distemper-measles virus	One dose only between 4-12 wk old	Not indicated animals over 12 wk	Not indicated animals over 12 wk	Noncore
Canine adenovirus-1				Not recommended. Significant risk of hepatitis blue-eye. CAV-2 cross protect against CAV-1
Canine adenovirus-2 (MLV)	Administer 6-8 wk of age, then every 3-4 wk until 12-14 wk old	Two doses 3-4 wk apart	One year booster at 15 mo, then revaccination once every 3 yr considered protective	Core
Canine adenovirus-2 (killed)				Not recommended. CAV-2 (MLV) more effective
Canine parvovirus (MLV)	Administer 6-8 wk of age, then every 3-4 wk until 12-14 wk old	Two doses 3-4 wk apart	1- yr booster at 15 mo, then revaccination once every 3 yr considered protective	Core
Canine parvovirus (killed)				Not recommended. This vaccine susceptible to maternal antibodies
Canine parainfluenza virus (MLV)	Administer 6-8 wk of age, then every 3-4 wk until 12-14 wk old	One dose	One year booster at 15 mo, then revaccination once every 3 yr is considered protective	Noncore
Leptospira interrogans (canicola, icterohaemorrhagiae) (killed bacterin)	Administer 12 wk of age, then booster at 14-16 wk of age	Two doses 2-4 wk apart	Annual update	Core, noncore
Leptospira interrogans (canicola, icterohaemorrhagiae, pomona, grippotyphosa) (killed bacterin)	Administer 12 wk of age, then booster at 14-16 wk of age	Two doses 2-4 wk apart	Annual update	Core, noncore
**Bordetella bronchiseptica* (killed) – parenteral	Administer 6-8 wk of age, then one dose 4 wk later	Two doses 2-4 wk apart	Annual update	Noncore. Administer 1 wk before exposure
Bordetella bronchiseptica (live avirulent bacteria), parainfluenza (MLV) – intranasal	Administer single dose (may give as early as 3 wk of age)	One dose	Annual update	Noncore

Continued

Table 23-1 Canine and Feline Vaccinations—cont'd

Canine Vaccine	Initial Puppy Vaccination	Initial Adult Dog Vaccination	Revaccination	Comments
Bordetella bronchiseptica (cell wall antigen extract) – parenteral	Administer 8 wk of age, then repeat at 12 wk of age	Two doses 4 wk apart	Annual update	Noncore. Administer 1 wk before exposure
Canine coronavirus (killed and MLV)				Not recommended. Clinical disease rarely occurs, typically self-limiting
Rabies 1 yr (killed)	Administer as early as 12 wk of age	One dose	Annual update	Core. State, local or provincial laws apply
Rabies 3 yr (killed)	Administer as early as 12 wk of age	One dose	Revaccination 1 yr following initial vaccine, booster vaccines administered every 3 yr	Core. State, local or provincial laws apply
**Borrelia burgdorferi* (killed whole bacterin)	Administer 9-12 wk of age, then booster with second dose 2-4 wk later	Two doses 2-4 wk apart	Annual update	Noncore
**Borrelia burgdorferi* (recombinant-outer surface protein A)	Administer 9-12 wk of age, then booster with second dose 2-4 wk later	Two doses 2-4 wk apart	Annual update	Noncore
Giardia lamblia (killed)	Administer 8 wk of age, repeat in 2-4 wk	Two doses 2-4 wk apart	Annual update	Not recommended. Does not prevent infection

Feline Vaccine	Initial Kitty Vaccination	Initial Adult Cat Vaccination	Revaccination	Comments
Panleukopenia (MLV, killed), parenteral	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	Two doses 3-4 wk apart	1-yr booster after primary vaccines, then revaccination once every 3 yr considered protective	Core. MLV not for pregnant queens or kittens less than 4 wk of age
Panleukopenia (MLV), intranasal	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	One dose	1-yr booster after primary vaccines, then revaccination once every 3 yr considered protective	Core. Not for pregnant queens
Rhinotracheitis virus (MLV), parenteral, intranasal	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	One dose	One year booster after primary vaccines, then revaccination once every 3 yr considered protective	Core. Not for pregnant queens

Table 23-1 Canine and Feline Vaccinations—cont'd

Feline Vaccine	Initial Kitty Vaccination	Initial Adult Cat Vaccination	Revaccination	Comments
Rhinotracheitis virus (killed), parenteral	Administer 8-10 wk of age, repeat in 3-4 wk	Two doses 3-4 wk apart	One year booster after primary vaccines, then revaccination once every 3 yr considered protective	Core
Calicivirus (MLV, killed)	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	Two doses 3-4 wk apart	One year booster after primary vaccines, then revaccination once every 3 yr considered protective	Core. MLV not for pregnant queens
Calicivirus (MLV), intranasal	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	One dose	One year booster after primary vaccines, then revaccination once every 3 yr considered protective	Core. MLV not for pregnant queens
Rabies 1 yr (killed), parenteral	Administer as early as 12 wk of age	One dose	Annual update	Core
Rabies (recombinant), parenteral	Administer as early as 8 wk of age	One dose	Annual update	Core
Rabies 3-yr (killed), parenteral	Administer as early as 12 wk of age	One dose	Revaccination one year following initial vaccine, booster vaccines administered every 3 yr	Core. State, local or provincial laws apply
Leukemia virus (live canarypox vector), parenteral	Administer at 9 wk of age, repeat in 3 wk	Two doses 3 wk apart	Annual update	Core, noncore
Leukemia virus (killed), parenteral	Administer 8-10 wk of age, repeat in 3-4 wk	Two doses 3-4 wk apart	Annual update	Core, noncore
Chlamydia psittaci (MLV, killed), parenteral	Administer 6-8 wk of age, then every 3-4 wk until 12 wk old	Two doses 3-4 wk apart	Annual update	Noncore
Feline infectious peritonitis (MLV), intranasal	Not approved for cats less than 16 wk	Two doses 3-4 wk apart to cats 16 wk of age or older	Annual update	Not recommended. Efficacy of vaccine controversial
Microsporum canis (killed), parenteral	Not approved for cats less than 16 wk	First dose subcutaneously 16 wk or greater, second dose 12-16 days afterwards, third dose 26-30 days after second dose	Not stipulated	Not recommended

Continued

Table 23-1 Canine and Feline Vaccinations—cont'd

Feline Vaccine	Initial Kitty Vaccination	Initial Adult Cat Vaccination	Revaccination	Comments
Bordetella bronchiseptica (MLV), intranasal	One dose to cats 4 wk or older	One dose	Not stipulated	Not recommended. Primarily problem of very young kittens
Giardia lamblia (killed), parenteral	Administer 8 wk of age, repeat in 3-4 wk	Two doses 3-4 wk apart	Annual update	Not recommended. Same limitations as those listed for canine *giardiasis*
Feline immunodeficiency virus (killed), parenteral	Administer 8 wk of age, then every 2-3 wk for an additional 2 doses	Three doses 2-3 wk apart	Annual update	Not recommended. Vaccination of FIV (-) cats renders current available serologic tests positive

MLV, Modified live virus.

2. Diethylcarbamazine (DEC) works up to exposure 48 hours previously

B. General information about preventatives
1. Ivermectin and milbemycin are macrolide antibiotics
2. Avoid ivermectin with collies, collie mixes, Old English sheepdogs

C. Filaribits (DEC)
1. Must be given daily
2. Beef flavored (not for food trial)
3. Must not give to a microfilaria-positive dog; may cause anaphylaxis
4. Will be available until stock depleted

D. Filaribits Plus (DEC, oxybendazole)
1. Help control roundworm, hookworm, and whipworm infections
2. No longer available

E. Heartgard (ivermectin)
1. Nonflavored form may be used with food trials
2. Microfilaricidal at 5× the dose
3. Kills L3, early L4, and some L1 at the preventative dose
4. Sizes: 0-25 lb, 26-50 lb, 51-100 lb

F. Heartgard Plus (ivermectin, pyrantel)
1. Beef flavored (not for food trial)
2. Help control roundworm, hookworm infections
3. Sizes: 0-25 lb, 26-50 lb, 51-100 lb

G. Interceptor (milbemycin oxime)
1. Beef flavored (not for food trial)
2. Microfilaricidal at preventative dose
3. May be used in cats (same packaging)
4. Kills L3, early L4, and L1
5. Sizes canine: 2.3 mg 0-10 lb, 5.75 mg 11-25 lb, 11.5 mg 26-50 lb, 23 mg 51-100 lb
6. Sizes feline: 5.75 mg 1.5-6 lb, 11.5 mg 6.1-12 lb, 23 mg 12.1-25 lb

H. Sentinel (milbemycin, lufenuron)
1. Combination product of Interceptor and Program (lufenuron)
2. Lufenuron is a chitin inhibitor, thus not allowing flea eggs to hatch properly
3. Beef flavored (not for food trial)
4. Sizes: 0-10 lb, 11-25 lb, 26-50 lb, 51-100 lb

I. Revolution (moxidectin)
1. Topical product (may be used for food trial)
2. Kills L3, early L4, and some L1
3. Dogs: Also treats for sarcoptes, otodectes, American dog tick and fleas
4. Kills fleas by attacking the central nervous system (CNS)
5. Sizes for dog: 0-5 lb, 5-10 lb, 10.1-20 lb, 20.1-40 lb, 40.1-80 lb, 80.1-100 lb
6. Cats: Also treats for otodectes, fleas, roundworms, and hookworms
7. Sizes for cat: 0-5 lb, 5-15 lb

J. ProHeart 6/12 (moxidectin)
1. Taken off the U.S. market
2. Injectable (may be used with food trial)
3. Also treats all stages of hookworm disease
4. Two types available, lasting through a time release mechanism for 6 or 12 months

K. Heartgard Chewable for cats (ivermectin)
1. Flavored (not for food trial)
2. Also controls hookworm infestation
3. Sizes: 55 mcg 0-5 lb, 165 mcg 5-15 lb

L. Ivomec (liquid ivermectin): Off label use in small animal except for the ferret

M. Iverheart (ivermectin, pyrantel): Generic Heartgard Plus

N. Tri-Heart (ivermectin, pyrantel): Generic Heartgard Plus

O. Ivomec (liquid ivermectin)
1. Off-label use in small animal except for the ferret
2. Ferret: Combine 0.1 mL of Ivomec with 0.9 mL propylene glycol; administer 0.1 mL for each ferret monthly for heartworm protection

II. Flea preventatives

A. Frontline Top Spot (fipronil)
1. Topical application to skin in one location
2. Waterproof
3. Collects in oils of the skin and hair follicles, continues to be released onto skin and coat providing long-lasting activity
4. Fipronil attacks the flea's CNS

Table 23-2 Heartworm and Flea Preventives

Product (Age Approved for Use)	Heartworm	Fleas	Ticks	Round-worms*	Hook-worms*	Whip-worms*	Ear Mites	Sarcoptes	Mosquitoes
Canine Filaribits	x								
Canine Filaribits Plus	x			x	x	x			
Canine Heartgard (6 wk)	x								
Canine Heartgard Plus (6 wk)	x			x	x				
Canine Interceptor (4 wk)	x			x	x	x			
Canine Sentinel (4 wk)	x	x		x	x	x			
Canine Revolution (6 wk)	x	x	x				x	x	
Canine Iverheart (6 wk)	x			x	x				
Canine Tri-Heart Plus(6 wk)	x			x	x				
Heartgard for Cats (6 wk)	x				x				
Feline Interceptor (6 wk)	x			x	x				
Feline Revolution (8 wk)	x	x	x	x	x		x		
Canine Frontline Top Spot (10 wk)		x	x						
Feline Frontline Top Spot (8 wk)		x	x						
Canine, Feline Frontline Plus (8 wk)		x	x						
Advantage (7 wk dog, 8 wk cat)		x							
Canine Advantix Program (4 wk dog, 6 wk cat)	x	x x							x
Capstar (4 wk)		x							

*These products help control infections with these parasites.

5. Absorbed externally in the sebaceous glands surrounding the hair follicles
6. Treat for adult fleas, ticks, and chewing lice
7. May be used on breeding, pregnant, or lactating bitches or queens
8. Dog: Apply at 10 weeks of age; works against fleas for up to 90 days, ticks 30 days
9. Cat: Apply at 12 weeks of age; works against fleas for up to 6 weeks, ticks 30 days
10. Do *not* use on rabbits

B. Frontline Plus (fipronil, methoprene)
 1. Treats all life stages of the flea
 2. Methoprene is an insect growth regulator
 3. Same factors for Frontline Top Spot apply, except may apply on dogs and cats as early as 8 weeks of age

C. Advantage (imidacloprid)
 1. Water resistant
 2. Flea preventative only
 3. Topical application to skin in one location on the cat or a dog weighing 20 lb or less

4. Animals larger than 20 lb: Evenly applied to three or four sites on the top of the back from the shoulder to the base of the tail
5. Imidacloprid attacks the flea's CNS
6. Absorbed externally in the sebaceous glands surrounding the hair follicles
7. Do not treat more than once weekly
8. May be applied as early as 8 weeks of age in both dogs and cats

D. Advantix (imidacloprid, pyrethrin)
1. Water resistant
2. Flea and tick adulticide, mosquito repellant
3. Only for use in dogs, toxic to cats

E. Program (lufenuron)
1. Inhibits development of chitin, main component of flea's exoskeleton
2. Does not kill adult fleas
3. Comes in flavor tabs for dogs and cats, suspension for cats, 6-month subcutaneous injectable for cats
4. Is approved for pregnant or nursing dogs and cats

F. Capstar (nitenpyram)
1. Kills adult fleas by attacking the CNS
2. Can dose as often as once daily
3. Begins working within 30 minutes
4. Application lasts one day
5. Safe for pregnant or lactating bitches and queens
6. May be used with other products, including heartworm preventatives, corticosteroids, antibiotics, vaccines, deworming medications, shampoos, and other flea products
7. Does not have an effect on fleas in pet's environment
8. Administer once weekly until fleas are no longer observed
9. For severe infestation, administer twice weekly until fleas no longer observed
10. Do not administer to dogs or cats weighing less than 2 lb
11. Sizes canine: 11.4 mg 2-25 lb, 57 mg 25.1-125 lb
12. Sizes feline: 11.4 mg 2-25 lb

HEARTWORM DISEASE (*DIROFILARIA IMMITIS*)

I. Diagnostic testing
A. Heartworm disease has been documented in all 50 United States
B. The American Heartworm Society (AHS) recommends yearly heartworm testing even if preventative is given year round if there is any possibility of the owner missing one dose
C. AHS currently recommends that adult heartworm antigen tests be used as the primary method of screening
1. Enzyme-linked immunosrobent assay and immunochromatographic test systems available for detecting circulating heartworm antigen
2. Improved accuracy of test kits
3. Simplicity of use
4. Greater overall sensitivity than microfilaria tests, especially with monthly products killing or decreasing total numbers of circulating microfilaria
5. Immunoassays detect circulating heartworm antigen from adult female reproductive tract
6. Consistently detect at least three adult female worms
7. Weak positive test results may be rechecked
8. Should test for microfilaria to validate heartworm positive status; indicates affected animal reservoir

D. Microfilaria testing
1. Direct smear assessing fresh blood for movement
2. Movement beneath buffy coat in spun hematocrit tube
3. Concentration techniques: Millipore filtration test, modified Knott test
4. Circulating microfilaria found less than 20% of the time in cats; if microfilaria present in the cat, will only last in circulation for up to 1 month

E. Antibody testing (Table 23-3)
1. Detect both male and female L4 larval stage
2. Antibody testing only available for cats
3. Indicates exposure, current or past
4. Does not indicate whether L4 will develop into heartworm infection

II. Diagnostic workup for heartworm disease: Minimum database
A. Packed cell volume (PCV)/ total solids (TS)
1. PCV of 30% or less is cutoff for classifying as class 2
2. Anemia may be absent, mild, or moderate, depending on chronicity as well as severity of disease

B. Chemistry profile
1. Azotemia may occur in dogs with complicated infections
a. Prerenal azotemia may be due to dehydration or right-sided congestive heart failure (CHF)
b. Primary azotemia may result from glomerulopathies, including immune complex disease and amyloidosis
2. Increased serum hepatic enzyme levels may occur
3. Hypoalbuminemia occurs in some dogs with severe infections and hyperglobulinemia, which is common in dogs and cats with chronic heartworm disease

C. Urinalysis
1. Proteinuria may occur due to antigen-antibody complex deposition
2. In absence of hypoalbuminemia, most cases of proteinuria resolve following heartworm treatment

D. Thoracic radiographs (Table 23-4)
1. Caudal lobar arteries most severely diseased; diameters should typically not exceed that of the ninth rib

Table 23-3 Differences between Heartworm Infection in Dogs and Cats

Differences	Dog	Cat
Parasite	*Dirofilaria immitis*	*Dirofilaria immitis*
Susceptibility to infection	Very high, virtually 100%	61%-90% exposed become infected
Time of development from L3 to L6	6 mo	7-8 mo
Average number of adult worms	20-30	1-3
Microfilaria present	80%-90%	<20%, last approximately 1 mo in circulation
Ectopic infections	Uncommon	Common
Testing	Occult heartworm test, millipore filtration test, modified Knott's test	Antibody testing, occult heartworm test
Longevity of infection	5-7 yr	2-3 yr
Clinical signs	Asymptomatic, coughing, exercise intolerance, dyspnea, signs of congestive heart failure	Asymptomatic, coughing, signs of congestive heart failure, vomiting, diarrhea, neurologic signs, sudden death
Immune response		Spontaneously resolve infection
Organ of greatest pathology	Lungs and heart	Lungs
Treatment options	See treatment section in text	See treatment section in text

Table 23-4 Criteria for Heartworm Infection Classification

Class	Clinical Signs	Radiographic Signs	Clinicopathologic Abnormalities
1 (Mild)	None; or occasional cough, fatigue on exercise, or mild loss of condition	None	None
2 (Moderate)	None; or occasional cough, fatigue on exercise, or mild to moderate loss of condition	Right ventricular enlargement and/or pulmonary artery enlargement; ± perivascular and mixed alveolar or interstitial opacities	± Mild anemia (PCV, 20% to 30%); ± proteinuria (2+ on dipstick)
3 (Severe)	General loss of condition or cachexia; fatigue on exercise or mild activity; occasional or persistent cough; ± dyspnea; ± right-sided heart failure	Right ventricular ± atrial enlargement; moderate to severe pulmonary artery enlargement; perivascular or diffuse mixed alveolar/interstitial opacities; ± evidence of thromboembolism	± Anemia (PCV <30%), ± proteinuria (≥2+ on dipstick)
4 (Very severe)	Caval syndrome		

PCV, Packed cell volume.

2. Tortuosity of pruning of arteries
3. Cranial lobar arteries should typically not exceed proximal portions of the third rib
4. Parenchymal lung disease results from pulmonary arteriolar thromboembolism with leakage of plasma and inflammatory cells into adjacent tissues
5. Severity of parenchymal lung disease varies; most prevalent in caudal and intermediate lung lobes and surrounding lobar arteries

III. Pathophysiology of heartworm disease
 A. Heartworm disease is the most common cause of pulmonary hypertension (cor pulmonale) in dogs and is increasingly recognized in cats
 B. Adult worms live mainly in the pulmonary arteries. As the worm burden increases, some worms move into the heart. May eventually even enter the caudal vena cava

C. Cycle of endothelial cell and worm interaction causes changes in pulmonary arteries. Caudal and accessory lobar arteries most severely affected
D. Leads to pulmonary edema
E. Dead worms incite a more intense host response
F. Worm fragments and thrombi cause embolization and worsen pulmonary disease
G. Vessels become tortuous and proximally dilated as the increased pulmonary vascular resistance demands higher perfusion pressures
H. Leads to right-sided heart disease
I. Chronic hepatic congestion secondary to heartworm disease can cause permanent liver damage and cirrhosis. Circulating immune complexes or possibly microfilarial antigens can produce glomerulonephritis
J. Occasionally, aberrant worms can cause embolization of the brain, eye, or other systemic arteries. May also see allergic pneumonitis or lymphoid granulomatosis

IV. Treatment of heartworm disease in the dog
A. Adulticides
1. Thiacetarsamide sodium (Caparsolate)
a. Arsenical
b. Older version of treatment
c. Four doses total, one dose administered intravenously every 12 hours
d. Potential tissue slough if leakage outside of vein; test each time by injection of saline
e. Acute toxicity occurs in 10% to 20% of patients
f. Contraindications: Hepatic failure, nephrotic syndrome, advanced renal failure, right-sided CHF, and azotemia or any life-threatening disorder
2. Immiticide (melarsomine)
a. Arsenical
b. Less hepatotoxic and improved efficacy against both sexes of adult worms
c. Soreness and mild swelling may occur at injection site for a few days, but this can be minimized by ensuring that the injection is deposited deeply with a needle of appropriate length and gauge for the size of the dog
d. Exercise restriction is essential for minimizing cardiopulmonary complications
e. Two treatment options
(1) Two deep injections administered intramuscularly (IM), alternating sites, given 24 hours apart
or
(2) Give one deep injection IM, wait and rest dog for 30 days, then give two deep IM injections 24 hours apart
(3) Choice is based on history, physical examination, thoracic radiographs, PCV/TS, chemistry profile, and urinalysis
(4) The three-injection alternative is the treatment of choice of the AHS, many universities, and private practitioners, regardless of the stage of disease
3. Ivermectin (Heartgard)
a. Exercise restriction still required
b. Continuous monthly administration of prophylactic doses highly effective against late precardiac larva and young adult heartworms
c. Adulticide effect will require longer than one year, possibly up to 2 years total
d. During the course of treatment, the infection persists, disease progresses
e. Older worms will take longer to die than do younger worms
f. Long-term administration of ivermectin is not a substitute for conventional arsenical adulticide treatment
g. Dogs with chronic mature infections might not benefit

B. Microfilaricidals
1. Ivomec (Ivermectin)
a. Give at 4 weeks after adulticide treatment
b. Administer in the morning, hospitalize the patient to monitor throughout the day for signs of vomiting, depression, diarrhea, and cardiovascular instability
c. Associated with few complications
d. Not recommended for collies or shelties
2. Interceptor (milbemycin oxime)
a. Normal preventative dose is a microfilaricidal
b. Most potent microfilaricide at the label dose; produces the most rapid rate of clearance
c. Rapid death of large numbers of microfilaria 4 to 8 hours following the first dose; can cause systemic side effects such as lethargy, inappetence, salivation, pale mucous membranes, and tachycardia
3. Heartgard (ivermectin). Must dose 4 to 5× higher than preventative dose for microfilaricidal use

C. Follow-up
1. Perform microfilarial concentration test 3 to 4 weeks following microfilaria treatment
a. If negative, begin heartworm preventative immediately
b. If positive, repeat treatment for microfilaria, then repeat microfilarial concentration test in another 3 weeks
2. Testing for adult heartworms through the occult heartworm test should occur 100 days or 4 months following the end of the last dose of immiticide administered, regardless of which protocol was chosen
a. If tested prior to 100 days, false-positives may occur because of persistent circulating antigen presence
b. If positive, decide to repeat adulticide therapy or wait 6 to 12 months based on young, female, drug-resistant worms being present
c. If weakly positive, repeat test in 1 to 3 months

V. Treatment of heartworm disease in the cat
 A. If asymptomatic, do nothing, and begin or continue heartworm preventative
 B. If clinical, treatment based on clinical signs exhibiting
 C. Surgical removal: Do not break a worm; may cause acute anaphylactic reaction and death of the patient
 D. Adulticide therapy: 30% of cats receiving this treatment will have a life-threatening crisis within 3 weeks of therapy

Supplemental Reading

2005 Executive Board of the American Heartworm Society. 2005 Guidelines for the Diagnosis, Prevention and Management of Heartworm (Dirofilaria immitis) Infection in Dogs. Available online www.heartwormsociety.org.

Report of the American Animal Hospital Association (AAHA) Canine Task Force. 2006 AAHA Canine Vaccination Guidelines. Available at www.aahanet.org/PublicDocuments/VaccineGuidelines06Revised.pdf.

24 CHAPTER

Reproductive Disorders

Patricia A. Schenck

PROSTATE GLAND DISORDERS

I. Clinical signs
 A. Clinical signs are varied. Systemic signs include depression, anorexia, and vomiting. Hematuria or blood dripping from the prepuce are the most common clinical signs
 B. Other clinical signs include urethral discharge, stranguria, fecal tenesmus, diarrhea, recurrent urinary tract infection, abdominal distension, caudal abdominal pain, lumbar pain, hindlimb stiffness, hypertrophic osteopathy, hindlimb pitting edema, urinary incontinence, infertility, impaired libido, perineal tumor, sepsis, or testicular tumor

II. Physical examination
 A. Rectal examination is essential. Palpate ventrally for the prostate and dorsally for lymph nodes
 B. Evaluate the prostate gland for size, location, symmetry, pain. Normally the prostate is symmetric, bi-lobed, within the pelvis, moveable, and not painful. As the prostate enlarges, it may move cranially; thus, concurrent abdominal palpation is sometimes useful
 C. Abdominal palpation may reveal the presence of a mass, distension, or pain

III. Diagnostic tests
 A. Laboratory findings
 1. Neutrophilic leukocytosis is often associated with bacterial prostatitis. Increased alkaline phosphatase (ALP) may accompany bacterial prostatitis or neoplasia
 2. Urine sediment examination or culture may be negative in dogs with bacterial prostatitis or abscess
 3. Prostatic fluid cytology or culture is necessary for diagnosis of bacterial prostatitis
 B. Imaging
 1. Abdominal radiography may reveal associated disorders such as prostate enlargement or asymmetry, mineralization, lymph node enlargement, bone periosteal reactions, urine or fecal retention
 2. Iliac lymph node enlargement and prostate mineralization are often associated with prostatic neoplasia
 3. Ultrasound examination may evaluate prostate size and location and help to obtain biopsy specimens
 C. Specimen collection
 1. Ejaculate specimen
 a. The dog should be handled in a quiet environment, and exposure to a female in estrus may be helpful
 b. Advantages are that this technique is safe, inexpensive, easy to perform, and gives specimens for bacterial culture
 c. Disadvantages are that this specimen is not useful for cytology, a positive bacterial culture does not localize the disease, and the animal must be compliant
 2. Prostatic wash specimens are useful for microbiology and cytology
 a. Urine or urethral contamination may occur, and if there is concurrent bacterial cystitis, microbiology results cannot be interpreted
 b. Rectal massage may not reach the prostate and can rupture a prostatic abscess
 3. Urethral brush specimen
 a. Advantages include localization, urethral contamination is minimized, and useful cytologic and microbiologic information is obtained
 b. However, the specimen brush cannot be reused, so the technique is expensive, the prostate gland may not be reached for effective rectal massage, and vigorous massage may rupture an abscess
 4. Ultrasound-guided prostatic aspirate uses ultrasound to guide the insertion of a needle into the prostate gland
 a. Advantages are that it localizes the source of bacterial infection and is relatively safe
 b. Disadvantages are that sedation and anesthesia are usually necessary, specialized equipment and skill is required, and aspiration of an abscess or tumor can lead to peritonitis or seeding the abdomen with neoplastic cells
 5. Prostate gland biopsy
 a. Evaluate coagulation status
 b. Approaches include transperineal, transabdominal, laparotomy, laparoscopy
 c. Sedation or anesthesia is necessary
 d. If ultrasound is not available, biopsy through laparotomy is the most accurate technique

IV. Disorders
 A. Benign prostatic hyperplasia (BPH)
 1. BPH is the most common prostate disorder
 2. Dihydrotestosterone is the main androgen promoting hyperplasia
 3. Castration is an effective treatment
 4. Megestrol acetate or finasteride can be used in breeding dogs without a loss of fertility
 5. Estrogens should not be used
 6. Delmadinone acetate, an androgen inhibitor, can be used but is contraindicated for breeding dogs
 B. Cystic hyperplasia
 1. Multiple fluid-filled cysts result from obstruction of glandular excretory ducts
 2. Usually associated with BPH and squamous metaplasia
 C. Squamous metaplasia
 1. Caused by estrogen stimulation either from an exogenous source or a Sertoli cell tumor
 2. Castration is the treatment of choice. Discontinue any exogenous source of estrogen
 D. Prostatic infection
 1. Infection is usually ascending, and causes are prostatic hyperplasia or cysts, urinary tract infections, altered urine flow, urethral abnormalities, or immune dysfunction
 2. *Escherichia coli, Staphylococcus, Proteus mirabilis, Streptococcus*, and *Mycoplasma* are the most common causes
 3. Fungal organisms such as *Blastomyces, Cryptococcus,* or *Coccidioides* can also cause prostatitis
 4. Antibiotics for treatment should be lipid soluble to penetrate the prostate. Most effective antibiotics include trimethoprim-sulfa, clindamycin, enrofloxacin, erythromycin, chloramphenicol, and oleandomycin. Antibiotics should be given for a minimum of 4 weeks
 5. A good initial treatment choice is trimethoprim-sulfa, enrofloxacin, or chloramphenicol
 6. Evaluate patient for septicemia or peritonitis
 7. Castration decreases the potential for recurrence but should not be performed until the patient has been receiving antibiotics for a few weeks
 E. Idiopathic prostatitis
 1. Cause is unknown, but the signs are similar to those of bacterial prostatitis
 2. Castration is probably beneficial. Antibiotics, corticosteroids, anticholinergics, and muscle relaxants have been used
 F. Paraprostatic cysts
 1. Paraprostatic cysts are adjacent to the prostate gland and result from fluid accumulation in embryologic remnants
 2. Surgery is recommended. Antibiotics may also be needed if there is septicemia or peritonitis
 G. Prostatic abscesses
 1. Abscesses occur as a sequel to infection with obstruction of excretory ducts or as secondarily infected cysts
 2. Surgery is recommended. Antibiotics may also be needed if there is septicemia or peritonitis
 H. Prostatic neoplasia
 1. Adenocarcinoma and transitional cell carcinoma are most common
 2. Castration does not prevent the development of prostatic tumors
 3. Metastasis to lymph nodes, bones, and organs is common
 4. Intraoperative radiation therapy is the treatment of choice but is not recommended if metastases are present
 5. Prostatectomy is associated with complications including urinary incontinence and urethral stricture
 6. Castration is of questionable benefit, and chemotherapy is not effective
 7. Total androgen blockade with luteinizing hormone (LH)–releasing hormone, or ketoconazole has benefit by blocking androgen synthesis
V. Surgical highlights
 A. The hypogastric and pelvic nerves are closely associated with the vasculature and are necessary for micturition and continence. Avoid damage to these nerves during any surgical procedure
 B. The prostate gland encompasses the male urethra at the neck of the urinary bladder
 C. The prostate is found in the pelvic cavity until about 4 years of age and is entirely within the abdomen by about 10 years of age
 D. Surgical procedures require a ventral midline incision
 E. Urinary incontinence is common with total prostatectomy
 F. If prostatectomy is performed because of prostatic neoplasia, metastasis is common to the median iliac lymph nodes, periprostatic tissue, urinary bladder, pelvic structures, and lung

DISORDERS OF THE TESTES

I. Clinical signs
 A. Infertility is common. There may be no clinical signs
 B. Pain and inflammation may be caused by infection, trauma, torsion, or immune-mediated disease. Swelling or a stiff gait may be noted, and licking of the scrotum may be observed
 C. Feminization may result from Sertoli cell tumors
II. Physical examination
 A. Two equal-sized and shaped testicles should be palpable in the scrotum. Testicular size can vary with breed and individuals
 B. Cryptorchidism is diagnosed on physical examination. Undescended testicles may often be found lateral to the prepuce or in the inguinal area
 C. An enlargement of one testicle suggests neoplasia, granuloma, spermatocele, varicocele, inflammation, or torsion
III. Diagnostic tests
 A. Laboratory tests aid in the diagnosis of inflammatory diseases, infectious diseases, neoplasia, and infertility

B. Brucellosis testing
 1. Usually tested using rapid slide agglutination test
 2. False-positives occur, so positive results should be confirmed by serology
C. Imaging: Ultrasound evaluation can detect undescended testicles or tumors
D. Semen evaluation
 1. Collection of semen
 a. Semen collection is relatively easy in the dog but difficult in the cat
 b. Retract the prepuce caudally and manually stimulate the penis. Collect semen using an artificial vagina or into a sterile cup
 c. There are three fractions to a canine ejaculate
 (1) First: Small volume or clear prostatic fluid
 (2) Second: Milky white sperm-rich fluid (0.5 to 5 mL)
 (3) Third: Large volume of clear prostatic fluid
 d. Do not collect semen from an animal with obvious inflammation of the testes
 2. Color, consistency, and cytology
 a. Presence of blood may indicate a traumatic collection or prostatic disease
 b. A nonopaque second fraction indicates oligospermia, and flecks of discolored debris are consistent with purulent material
 c. An air-dried slide of semen can be stained. Inflammatory cells or organisms may be identified
 3. Sperm count
 a. Use of hemocytometer to determine the number of sperm per milliliter of ejaculate. Multiply by the volume of the ejaculate to determine total sperm count
 b. A normal ejaculate contains more than 200 million sperm cells
 4. Motility and morphology
 a. Evaluate a drop of ejaculate placed on a warm microscope slide; 70% of sperm should be motile
 b. Morphologic abnormalities should not be present in greater than 20% of sperm
 c. Primary abnormalities include cytoplasmic droplets, thickened midpiece, or misshaped heads. Distal cytoplasmic droplets may indicate epididymal disease
 d. Secondary abnormalities such as coiled or bent tails or detached heads occur in the epididymis and distally
 5. Semen ALP
 a. Epididymis produces ALP, and a low activity in semen indicates the absence of epididymal fluid
 b. Azoospermia can result from blockage of the epididymis. Normal semen ALP is above 4000 international units per liter
 6. Semen culture
 a. To diagnose infectious orchitis-epidiymitis, use either semen sample or testicular fine-needle aspirate
 b. Contamination from the urogenital tract can occur
 c. With infection, there should be more than 10^5 colony-forming units/mL. Chronic infections can yield negative cultures
E. Fine-needle aspiration and biopsy
 1. Can reveal organisms, inflammatory cells, neoplasia, sperm. Chronic inflammation makes collection of fine-needle aspirates difficult
 2. Biopsy is indicated to investigate azoospermia if no other cause is found. Orchitis is an uncommon complication
F. Testicular feminization syndrome. Demonstrate bilateral testes, XY chromosomal status, and positive response to human chorionic gonadotropin

IV. Congenital disorders
 A. Cryptorchidism
 1. Common hereditary disorder. Toy breeds, boxers, German shepherd dogs, and Persians are predisposed
 2. Unilateral is more common than bilateral. Bilateral cryptorchidism causes sterility
 3. Castration is the treatment of choice
 B. Male pseudohermaphroditism. Dogs have XY chromosomes, testes (usually cryptorchid), and external or internal female genitalia
 C. Testicular feminization syndrome
 1. Dogs have XY chromosomes but partial or complete failure of masculinization
 2. Castrate: This is an X-linked inherited trait, so 50% of male offspring from a female carrier are affected, and 50% of female offspring are carriers

V. Acquired disorders of the testes
 A. Infectious orchitis-epididymitis
 1. Can arise from trauma, hematogenous spread, urinary tract, or prostate
 2. Aerobic bacteria are the most common. *Brucella canis* is also an important cause. *Mycoplasma, Blastomyces*, canine distemper virus, feline infectious peritonitis, and rickettsial infections may also occur
 3. Castration and antibiotic therapy are curative
 4. Brucellosis is not always eradicated even if long-term antibiotic therapy is used. These dogs should be castrated
 B. Immune-mediated orchitis: An immune response to spermatozoal antigens occurs when the blood-testis barrier is broken. Orchitis results with lymphocytic infiltration of the testes
 C. Testicular neoplasia
 1. Common in dogs; uncommon in cats. More common in cryptorchid dogs
 2. Primary tumors include Sertoli cell, interstitial cell tumors, and seminoma. They are typically slow to metastasize and are usually an incidental finding in older dogs
 3. Sertoli cell tumors can cause feminization, including hair loss, testicular atrophy, and squamous metaplasia of the prostate
 4. Castration is the treatment of choice

D. Trauma can lead to inflammation or ischemia
E. Testicular torsion
1. Can occur in descended or undescended testes
2. There is an acute onset of pain with swelling of the testicle and spermatic cord
3. Castration is the treatment of choice
F. Secondary testicular disorders occur secondary to endocrine diseases such as hypothyroidism, diabetes mellitus, and hyperadrenocorticism
G. Other testicular diseases
1. Spermatocele is a dilation of the duct system that contains sperm. It is usually benign
2. Varicocele is a dilation of the spermatic vein. It can be benign but may thrombose
3. Sperm granuloma develops when sperm cells accumulate in the spermatic ducts

VI. Surgery
A. Anatomy
1. In the scrotum, the testis is covered by peritoneum (parietal and visceral vaginal tunics) and the tunica albuginea (a white fibrous capsule)
2. The caudal ligament connects the testis and epididymis to the parietal vaginal tunic
3. The pampiniform plexus in the spermatic cord is the major blood supply
B. Orchidectomy in the dog
1. When testes are in the scrotum, either a closed or open technique can be used
a. Make the incision in the prescrotal skin on the midline. Expose the testes either by leaving the parietal vaginal tunic intact or by incising through it
b. Double-ligate the spermatic cord using absorbable material
c. Transect and close the subcutaneous tissue and skin using absorbable sutures
2. Cryptorchidism
a. Make an incision on the ventral midline from the umbilicus to pubis while avoiding the prepuce
b. Locate the intraabdominal testis
c. Double—ligate the vessels and ductus deferens
d. Transect and remove the testis
e. Routine closure of the abdomen
3. Complications include bruising, inflammation of the scrotum, hemorrhage, or infection
C. Orchidectomy in the cat
1. Incise the scrotum and expose the testis
2. Ligate the spermatic cord either with absorbable suture material or with the spermatic cord itself
3. Remove the testis
4. Do not suture the scrotum

DISORDERS OF THE SCROTUM

I. Causes
A. Contact dermatitis from soaps and other substances
B. Neoplasia such as squamous cell carcinoma, mast cell tumor, malignant histiocytic disease
C. Environmental injury from frostbite or sunburn
D. Drug eruption
E. Trauma
F. Self-mutilation associated with orchitis, granuloma, or pruritus
G. Scrotal hernia in which abdominal contents herniated through a defect in the inguinal ring. Swelling in the scrotum is noted, and strangulation of the hernia can cause severe pain

II. Diagnosis and treatment
A. Identify the underlying cause via thorough medical history and appropriate testing
B. Ultrasound may help identify tumors, scrotal hernia, or testicular adhesions
C. Scrotal hernia repair includes castration and closure of the defect in the inguinal ring
D. Scrotal ablation may be performed in the case of severe lesions

III. Surgery
A. Indications include trauma, neoplasia, ischemia, abscess, orchidectomy in older dogs, and urethrostomy
B. Surgery is done with the animal in dorsal recumbency. The skin is incised in an elliptical, curvilinear fashion near the base of the scrotum. Transect the scrotal septum and close the subcutaneous tissue and skin
C. Postoperative analgesia should be considered, and self-inflicted trauma should be minimized. Complications include hemorrhage, infection, and dehiscence

DISORDERS OF THE PENIS AND PREPUCE

I. Clinical signs may include preputial discharge, hemorrhage, abnormal urination, pain, swelling, inflammation, persistent erection, or failure to copulate

II. Physical examination should also include a rectal examination
A. The prepuce should move freely, and the penis should be easily extruded. There should be no pain. A small amount of greenish discharge is normal in dogs but not in cats
B. The penis should be moist, light pink, with a palpable os penis in dogs. Fractures of the os penis may be palpable. In cats, sedation may be needed. The intact male cat should have small barbs on the penis
1. Investigate any swelling, and in cases of trauma, pass a urethral catheter to assess patency
2. If the penis is erect, determine whether the prepuce is restricting the retraction. The preputial skin may be inverted, or there may a ring of hair encircling the penis. If there is no preputial restriction, try applying a cold compress

III. Diagnostic tests
A. Tests may include complete blood cell count (CBC), serum chemistries, urinalysis, cytology, imaging, or karyotype analysis
B. With balanoposthitis, large numbers of bacteria, toxic neutrophils, or fungal organisms may be identified on cytology. Cytology may also reveal neoplastic cells

C. Culture of the preputial discharge is usually not helpful
D. Radiographs may reveal a fractured os penis. Contrast retrograde urethrography can evaluate the patency of the urethra
E. Karyotype analysis requires fresh blood submitted in lithium heparin and may be necessary for sex differentiation disorders

IV. Congenital disorders are uncommon. Clinical signs result from the inability to extend the penis out of the prepuce or the inability to retract the penis
A. Persistent penile frenulum
1. This condition results when the surface of the glans penis and the preputial mucosa fail to separate along the ventral midline. This leaves a thin band of connective tissue joining the ventral midline of the penis and prepuce
2. The penis is unable to extend from the prepuce
3. This band of tissue is not very vascular, and treatment consists of surgically cutting the band and controlling any bleeding
B. Hypospadia
1. Abnormal closure of the urethral tube results in abnormal urethral openings anywhere along the urethra. Commonly the abnormal opening is on the ventral penis, but it may extend through the scrotum to the perineum
2. Hypospadia is caused by an androgen receptor defect and may be associated with abnormal development of the penis and prepuce
3. Most common in Boston terriers
C. Penile hypoplasia can occur with failure of masculinization or XX sex reversal syndromes where ambiguous genitalia are noted
1. If androgens are present during development, female pseudohermaphroditism may result. Clitoral enlargement may mimic penile hypoplasia
2. Urine may pool with penile hypoplasia and cause irritation of the prepuce
D. Phimosis occurs if the preputial opening is too small to allow extension of the penis. Urine pools in the prepuce and causes irritation
E. Os penis deformity may result in deviation of the penis and cause problems with copulation

V. Acquired penile disorders
A. *Priapism* is persistent, abnormal penile erection
1. Priapism is a medical emergency. Stasis of the blood due to failure of venous outflow from the erect penis can lead to ischemia and necrosis
2. Protect the penis against exposure and damage with frequent applications of sterile lubricant. Replace the penis in the prepuce and apply a temporary pursestring suture at the orifice if necessary
3. If nonischemic, antihistamines or anticholinergics such as diphenhydramine, atropine, or benztropine can be used. Advanced ischemia and necrosis may require amputation of the penis
B. Trauma
1. Damage may be evident, or there may only be signs of swelling, inflammation, and pain
2. Clean and suture as needed. Systemic antibiotics should be used in the case of open wounds. The penis should be extended two to three times per day and cleansed with dilute chlorhexidine to prevent adhesions. Ensure patency of the urethra
C. Foreign body
1. Can include plant material and other small materials and can result in swelling, inflammation, and balanoposthitis
2. Objects may become lodged in the prepuce or may encircle the penis, resulting in constriction
D. Neoplasias are uncommon
1. Transmissible venereal tumor (TVT) is seen in young dogs as a red, irregular mass on the penis. It is sexually transmitted and can also affect females. TVT may undergo spontaneous remission, or it may require treatment with vincristine or radiation therapy
2. Preputial tumors are usually mast cell tumors or TVT
3. Urethral tumors can involve the penis. Osteosarcoma of the os penis has been reported
E. Balanoposthitis is inflammation of the penis and prepuce
1. Usually caused by bacteria, which can be secondary to malformation, trauma, foreign body
2. May also be due to herpesvirus or fungal agents (blastomyces)
3. Common in dogs but uncommon in cats
4. Clean the prepuce with antiseptic, apply topical antibiotic cream, and treat the underlying cause. An Elizabethan collar may be necessary to prevent licking
F. Paraphimosis occurs when the penis is unable to retract into the prepuce
1. Penile mucosa adheres to the prepuce, the prepuce rolls inward, and prevents the retraction of the penis
2. This can lead to edema, ischemia, and necrosis of the penis
3. Sedation or anesthesia may be necessary. Cleanse and lubricate the penis, and remove constricting hair or foreign material. Apply a cool compress to reduce edema, and restore the normal anatomic position of the penis. If there is mucosal damage to the penis, apply topical antibiotic cream
4. If the damage to the penis is severe, amputation may be necessary

DISORDERS OF THE OVARIES AND UTERUS

I. Disorders of the ovaries
A. Ovarian remnant syndrome
1. Results from incomplete removal of all ovarian tissue at time of ovariohysterectomy
2. Signs of estrus recur between 1 and 3 years after ovariohysterectomy

3. High progesterone or low LH concentrations in a spayed female suggest an ovarian remnant
4. Treatment is to remove the ovarian remnant

B. Ovarian neoplasia
1. Cause
 a. Dogs: Granulosa cell tumors (associated with hyperestrogenism), adenoma, adenocarcinoma, germ cell tumors
 b. Cats: Granulosa cell tumors, teratoma
2. Clinical signs may be absent. Granulosa cell tumors may cause signs of increased estrogen, such as persistent estrus, and gynecomastia
3. Abdominal radiography/ultrasound aids in the diagnosis
4. Treatment is ovariohysterectomy

II. Diseases of the uterus

A. Pyometra
1. Bacteria from the lower genital tract can ascend into the uterus causing infection. The most common bacteria is *E. coli*
2. Previous treatment with estrogens or progestins may predispose
3. Clinical signs
 a. Vaginal discharge with a history of estrus in the preceding weeks should raise suspicion for pyometra. Vaginal discharge may not be present in all cases though
 b. General signs of systemic illness are often present (e.g., depression, dehydration, polyuria, vomiting, inappetence)
2. Diagnosis is based on history, clinical signs, radiography, CBC showing neutrophilia, and vaginal cytology and culture
3. Treatment
 a. Fluid therapy should be aggressive and antibiotic therapy broad-spectrum
 b. Ovariohysterectomy is the best method of treatment
 c. Prostaglandin therapy can be used in a valuable breeding female. Use of prostaglandins increases the risk of pyometra during subsequent estrous cycles

B. Diseases of the pregnant uterus
1. Diseases during pregnancy can result in abortion
2. In dogs, infectious diseases caused by *B. canis* and herpesvirus are most important. In cats, feline panleukopenia virus and herpesvirus are most important
3. Most affected animals have no clinical signs other than abortion

C. Normal parturition
1. Refusal of food and nesting behavior typically precedes parturition
2. Active contractions start about 6 to 12 hours later
3. Delivery of the first puppy or kitten occurs about 2 to 4 hours after contractions start
4. It is not abnormal for a puppy or kitten to be born feet first
5. Deliveries can occur in rapid succession, or there can be about 2 hours between births
6. Intense contractions should produce a puppy or kitten in less than 20 minutes
7. Placentas may be delivered with each fetus or might not be delivered until the entire litter has been born
8. A dark green discharge is common during and following labor

D. Dystocia
1. Causes
 a. Dystocia is common in dogs. Toy breeds and brachycephalic breeds are predisposed because of their large heads and small pelvic canals
 b. In cats, the Devon rex is predisposed
 c. Uterine inertia may be common in some breeds. It may be due to fatigue, hypoglycemia, hypocalcemia, or an unknown cause
 d. Oversized puppies can be a cause of dystocia. Oversized puppies may be more prevalent in single pup or small litters
2. Diagnosis: History, physical examination, and radiographs or ultrasound are most important
3. Treatment
 a. If there is no obstruction, oxytocin therapy can be attempted. If fetus not delivered within 30 minutes, perform cesarean section
 b. Cesarean section should be done if there is uterine inertia, there has been failure to respond to oxytocin, there is evidence of an oversized fetus, there is evidence of fetal death, or the female has become hypcalcemic or hypoglycemic

E. Postpartum uterine disorders
1. Bacterial metritis
 a. Occurs usually within a week after parturition and is characterized by a foul-smelling, mucopurulent discharge. Systemic illness may be present
 b. Perform abdominal ultrasound or obtain radiographs to detect retained fetuses
 c. Ovariohysterectomy and antibiotic therapy are necessary
2. Uterine prolapse
 a. Rare but can occur postparturition
 b. Treatment is manually to reduce the prolapsed tissue or to remove it if ulcerated or necrotic
3. Subinvolution of placental sites
 a. Uterine involution is usually complete by 6 weeks postpartum in the dog but may last for 3 months. A mucoid, brownish or hemorrhagic vaginal discharge is normal. Persistent bleeding for longer than 6 weeks is the typical clinical sign
 b. Usually resolves without treatment

F. Uterine neoplasia
1. Tumors are rare in dogs and cats
2. In the dog, leiomyoma and leiomyosarcoma are the most common. In the cat, endometrial adenocarcinoma is most common
3. Tumors may be found incidentally or may cause vaginal discharge or bleeding in some animals
4. Ovariohysterectomy is the treatment of choice

III. Surgery of the ovaries and uterus
 A. Anatomy (Figure 24-1)
 1. The ovaries are located caudal to the kidneys and are attached to the abdominal wall by the mesovarium. The suspensory ligament extends between the last two ribs and the ovary. The proper ligament extends from the ovary to the uterine horn. The blood supply to the ovaries is through the ovarian arteriovenous complex on the medial side of the broad ligament
 2. The uterus is attached to the abdominal wall by the broad ligaments. The round ligament extends through the broad ligament and passes through the inguinal canal. The blood supply to the uterus is mainly from the uterine branch of the internal iliac artery
 B. Ovariohysterectomy
 1. The incision should be started at the umbilicus and extend caudally down the ventral midline in the dog. In the cat, the incision should be started a few centimeters caudal to the umbilicus
 2. Make sure to clamp and ligate the blood supply to the ovaries. Avoid ligating the ureters. Ensure that all ovarian tissue is being removed
 3. Remove the uterus proximal to and close to the cervix
 4. Complications
 a. Hemorrhage is the most common complication
 b. Uterine stump pyometra can occur if a portion of the uterine body is not removed
 c. Ovarian remnant syndrome can result if the ovarian tissue is not completely removed
 d. Accidental ureteral ligation leads to hydronephrosis
 e. Urinary incontinence can occur in some females
 C. Cesarean section (Figure 24-2)
 1. Ventral midline incision. Incise cautiously to avoid lacerating the large uterus
 2. Exteriorize the uterus and incise in an avascular area
 3. Move the fetus to the incision with gentle squeezing of the uterine horn
 4. Remove fetus, remove the amniotic sac, and tie off the umbilical vessels
 5. Close the uterus with absorbable suture material in an inverting suture pattern
 6. Lavage the uterus before returning to the abdominal cavity, and lavage the abdominal cavity if any contamination with uterine contents occurred
 7. Complications
 a. Puppies may be depressed from the anesthetic agents used. They may need a respiratory stimulant such as doxapram. Keep puppies warm, and have them nurse as soon as possible
 b. Hemorrhage, peritonitis, dehiscence, or agalactia are the most common complications

DISORDERS OF THE VULVA, VESTIBULE, AND VAGINA

I. Congenital abnormalities: These conditions may prevent natural breeding, or they may contribute to chronic infections of the urinary or reproductive tracts
 A. Vulvar hypoplasia
 1. A small vulva frequently is not associated with any clinical abnormalities
 2. If perivulvar skin folds surround and recess the vulva, inflammation and bacterial growth can occur
 3. Secondary vaginitis, cystitis, or ascending urinary tract infection can occur
 4. Topical or systemic antibiotics are used to treat secondary infection

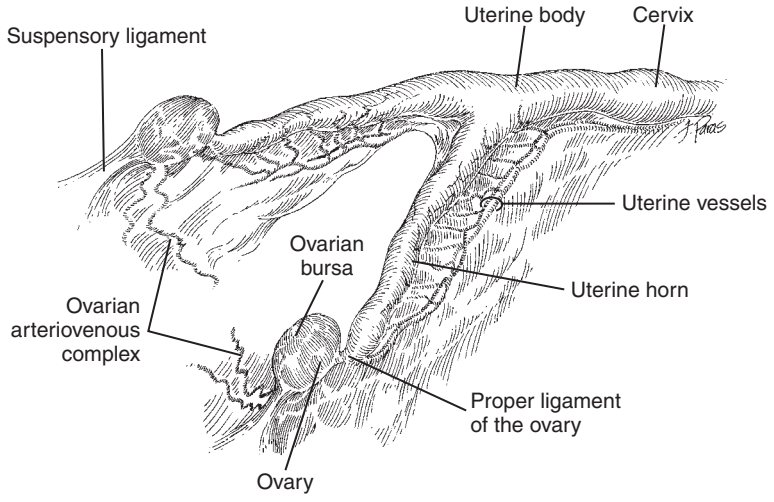


Figure 24-1 Anatomy of the uterus and ovaries. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice*, 3rd ed. St Louis, 2006, Saunders.)

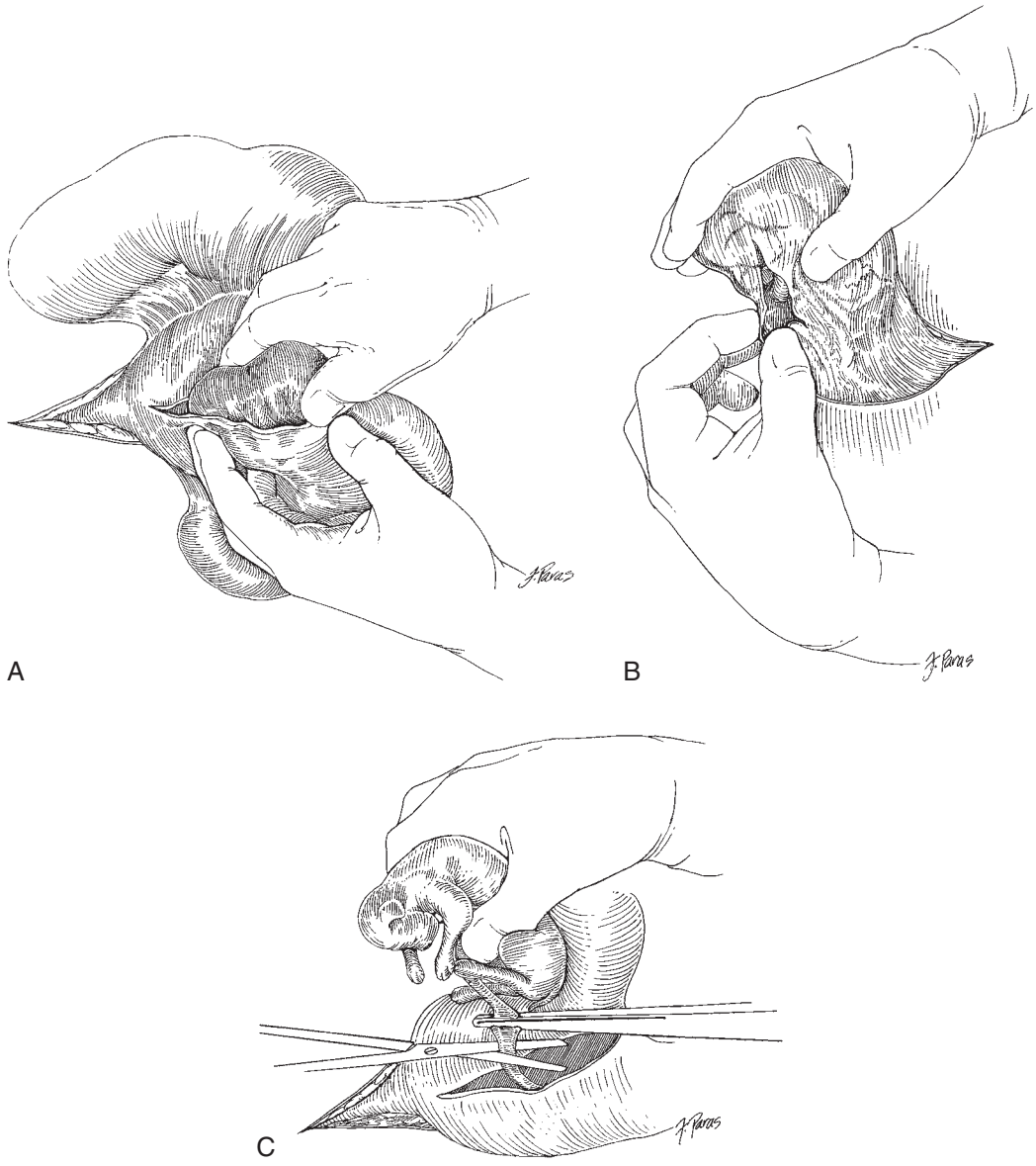


Figure 24-2 Cesarean section. **A,** Move the fetus toward the incision. **B,** Break the amniotic sac as the fetus is removed. **C,** Clamp and transect the umbilical vessels. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Clinical Practice,* 3rd ed. St Louis, 2006, Saunders.)

5. Episioplasty to excise excessive perivulvar skin folds is the treatment of choice if secondary infections occur

B. Vulvar stenosis
 1. Most common in collies and Shetland sheepdogs
 2. Common clinical sign is pain during mating
 3. Vulvar stenosis can result in dystocia, and a cesarean section may be needed
 4. Treatment is to enlarge the vulvar orifice by episiotomy

C. Vestibulovaginal stenosis (persistent hymen)
 1. Persistent vertical bands of tissue at the vestibulovaginal junction, common at the cingulum
 2. May be due to incomplete fusion of paramesonephric ducts
 3. Commonly seen in association with developmental abnormalities of the lower urinary tract
 4. Clinical signs that may be associated are chronic vaginitis, discharge, cystitis, or urine pooling
 5. Bands of tissue can be easily removed. Complete resection of an annular stricture is difficult and time consuming

II. Clitoral hypertrophy
 A. The clitoris may be enlarged with hyperadrenocorticism, exposure to anabolic steroids, or disorders of sexual differentiation
 B. Inflammation of the clitoris can lead to secondary urinary tract infections
 C. Treatment is to treat the underlying cause, and any secondary problems. Clitoral resection can also be performed

III. Vulvar enlargement
 A. Swelling is normal during estrus, but persistent swelling may suggest estrogenic stimulation from

cystic ovaries or ovarian tumor in the intact female or an ovarian remnant in a spayed female. Ovarian remnants are more common in cats
B. Vaginal cytology suggests estrogenic stimulation with mostly superficial and anuclear squamous cells. Serum estradiol or progesterone may be elevated
C. Treatment is to identify the source directly by exploratory laparotomy

IV. Vaginal edema (vaginal hyperplasia)
A. Normally occurs during the follicular phase of the estrous cycle, and spontaneously regresses in diestrus
B. May become inflamed, ulcerated, or necrotic if there is protrusion of the vaginal tissue through the vulvar orifice
C. Occurs most frequently in young females during their first estrus cycle
D. Keep proliferative tissue lubricated to prevent drying. Ovariohysterectomy for dogs not intended for breeding

V. Vaginal prolapse
A. Relatively uncommon, but the Boston terrier and boxer breeds appear to be predisposed
B. May result from dystocia
C. The protrusion has a doughnut appearance. This should be differentiated from vaginal edema
D. Keep clean and lubricated. Manually reduce the exposed tissues if possible. A hyperosmotic solution (50% dextrose) can be applied to help reduce edema
E. Ovariohysterectomy should be performed in females not intended for breeding
F. Surgical resection of ulcerated or necrotic tissue may be necessary

VI. Neoplasia
A. Leiomyoma is the most common neoplasm. Lipomas may also occur
B. Leiomyosarcoma is the most common malignant neoplasm. Others include squamous cell carcinoma, adenocarcinoma, mast cell tumors, hemangiosarcoma, and hemangiopericytoma.
C. Transmissible venereal tumor (TVT)
1. Proliferative tumor transmitted by sexual contact between animals
2. More common in younger, sexually active dogs
3. May be solitary or multiple friable or cauliflower-like lesions
4. May be found on the oral and nasal mucosa, skin, and perineum
D. Complete resection is treatment of choice. Chemotherapy (vincristine) is the treatment of choice for multiple TVT

VII. Vaginitis
A. Causes
1. Juvenile vaginitis generally occurs in female dogs before the first estrus, and it usually resolves without treatment
2. Bacterial vaginitis is uncommon but may occur secondary to urinary tract infection
3. Viral vaginitis is caused by herpesvirus and can result in infertility, abortion, and neonatal death
B. Diagnosis involves physical examination, vaginal cytology, urinalysis, culture and sensitivity, and possibly endoscopy or ultrasound
C. Treatment
1. Juvenile vaginitis usually resolves without treatment
2. Bacterial vaginitis may resolve with no treatment. Medical treatment involves appropriate antibiotics
3. There is no specific therapy for viral vaginitis. Affected females should not be used in a breeding program

INFERTILITY AND BREEDING DISORDERS AND ISSUES

I. Female dog
A. Normal estrous cycle
1. Anestrus
a. The period between estrous cycles
b. Low progesterone levels, high follicle-stimulating hormone (FSH) levels.
c. Between 4 to 18 months in duration is normal
2. Proestrus
a. Characterized by bloody vaginal discharge and vulvar swelling
b. Low progesterone levels, rising estrogen levels
c. Typically lasts between 3 and 14 days
3. Estrus
a. Starts when ovulation occurs and the female allows breeding
b. Ovulation occurs as the progesterone level starts to increase, resulting in LH release
c. The vulva becomes soft, and there is a clear (or slightly bloody) discharge
d. Lasts about 6 days
4. Diestrus
a. Lasts about 2 to 4 months if not pregnant, about 8 weeks if pregnant
b. Progesterone levels gradually decrease
c. Vaginal smear shows a change to parabasalar and intermediate cells, with the appearance of white blood cells
B. Abnormal estrous cycle
1. Persistent anestrus (failure to cycle)
a. Normal females may not cycle until 24 months of age
b. Evaluate thyroid function, cortisol production, and progesterone concentration
c. If normal, perform karyotyping, and consider endoscopy
2. Prolonged anestrus after an estrus cycle
a. If longer than 12 months, evaluate thyroid function, cortisol production, and progesterone concentration
b. Consider endoscopy to rule out ovarian abnormalities, especially ovarian cysts
3. Split estrus cycle
a. The bitch enters proestrus but does not ovulate
b. In about 4 to 6 weeks, the bitch will recycle and ovulate

 c. Progesterone testing is useful in determining ovulation in dogs with split cycles
4. Silent estrus
 a. A bitch can ovulate with no apparent signs of estrus
 b. Vaginal smears and serum progesterone determinations are helpful in determining the time of ovulation
5. Shortened anestrus
 a. About 4 months is needed between cycles
 b. If the breeding cycle is less than 4 months, infertility is common
 c. Mibolerone can be given daily to delay the onset of the estrous cycle
6. Prolonged estrus
 a. Common in young bitches having their first estrous cycle
 b. If this occurs in older bitches, then an estrogen-secreting ovarian cyst is a possibility
 c. Vaginal cytology suggests estrogen as the cause of the bleeding (primarily superficial cells)
 d. Rule out other causes of vaginal bleeding

C. Conception failure
1. Poor semen quality: Check the stud dog for adequate semen production
2. Ovulation failure: Use serum progesterone concentrations to pinpoint ovulation
3. Improper timing of breeding: Use serum progesterone concentrations to pinpoint ovulation
4. Improper breeding methods
 a. In the uterus and oviducts, fresh semen lasts an average of 4 to 6 days, whereas frozen semen only lasts about 12 to 24 hours
 b. A "tie" greatly increases the chance of conception but is not necessary
 c. Semen must be deposited at the external opening of the cervix
 d. If the female refuses the male, ensure that ovulation has taken place with serum progesterone determination. Try changing the environment, or perform artificial insemination
5. Implantation failure
 a. Implantation occurs about 17 to 18 days after ovulation
 b. Disease within the uterus can decrease implantation
6. Resorption and abortion
 a. Resorption of fetuses can occur up to day 38 postovulation
 b. Numerous problems can cause resorption and death, including genetics, medications, disease, toxins
7. Premature luteolysis
 a. Progesterone is secreted by the ovary throughout pregnancy and is required to maintain pregnancy
 b. Premature luteolysis may result in premature loss of puppies
 c. Treat with an injectable progesterone compound

D. Prebreeding evaluation
1. Physical examination of both male and female
2. Both should be parasite-free, have current vaccinations, and on heartworm preventative
3. Vaginal culture is not necessary if there are no clinical signs
4. Brucellosis testing
 a. The female should be tested before each mating (even before the first mating). Frequently used males should be tested every 6 months
 b. Rapid slide agglutination test is commonly used but can have 20% false-positives
 c. If testing positive, the dog should be isolated and a confirmatory test performed (e.g., immunodiffusion, blood culture)

E. Pregnancy diagnosis
1. Ultrasound is useful after day 19 post-ovulation
2. Palpation is accurate within a narrow window between day 23 and 30 posto vulation
3. Serum relaxin concentration: Serum relaxin can be measured to predict pregnancy after day 26 postovulation
4. Radiography
 a. Useful after day 47 postovulation
 b. Commonly used to determine the number and size of pups

F. Estrus induction
1. A minimum of 4 months of anestrus is required
2. Both cabergoline and deslorelin can be used

G. Artificial insemination
1. Determine the time of ovulation
2. Ensure that sperm are viable and normal in appearance
3. With the female standing, deposit semen at the external opening of the cervix via an insemination rod. Use aseptic technique, and wear sterile gloves. Digitally feather the vestibule for about 1 minute, and restrict the activity of the female for a few hours
4. Artificial insemination may also be done transcervically or by surgical insemination directly into the uterus

H. Termination of pregnancy for mismating
1. Drugs can be used to lyse the corpus luteum during the second half of pregnancy
2. Prostaglandin $F_2 \alpha$ or cabergoline (antiprolactin drug) is used. Must confirm that all fetuses have been passed

II. Female cat

A. Normal estrous cycle
1. Anestrus: Cats are seasonally polyestrus and will continue to cycle throughout the year if not bred. Anestrus is longest when daylight is at a minimum
2. Proestrus
 a. Last 1 to 2 days
 b. Estrogen levels increase, and vocalization occurs

3. Estrus
 a. There is no vaginal bleeding
 b. The female accepts breeding by the male. The penis of the male stimulates the vagina, resulting in LH release
 c. Multiple breedings are usually necessary to increase the chance of pregnancy
4. Interestrous: If not bred, there is about a 5- to 14-day period before returning to proestrus
5. Diestrus: Progesterone concentration is elevated and lasts for about 60 to 65 days if pregnant and 45 to 50 days if not pregnant

B. Ovulation induction: Ovulation can be induced by hormonal stimulation with gonadotropin-releasing hormone (GnRH), vaginal stimulation, or breeding to a vasectomized male cat
C. Stimulation of estrus can be accomplished by FSH administration or by maximizing the exposure to sunlight
D. Artificial insemination
 1. Semen is usually collected with an electroejaculator
 2. Insemination is performed similarly to the female dog, using a volume of about 0.1 to 0.2 mL of semen
E. Estrus suppression: GnRH will stimulate ovulation and delay the start of the next cycle

Supplemental Reading

Graves TK. Diseases of the testes and scrotum. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 957-968.

Graves TK. Diseases of the penis and prepuce. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 973-977.

Graves TK. Diseases of the ovaries and uterus. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 978-991.

Hutchison RV. Infertility and breeding disorders. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1015-1025.

Kay ND. Diseases of the prostate gland. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 949-956.

McLoughlin MA. Diseases of the vagina and vulva. In Brichard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1001-1008.

25 CHAPTER

Respiratory Disorders

Michal Mazaki-Tovi

DIAGNOSTIC METHODS FOR RESPIRATORY DISEASES

I. Upper respiratory tract
 A. Nasal cavity diseases
 1. History
 a. Sneezing and nasal discharge are the common clinical signs. Gagging, reversed sneezing, or stertor may occur when the disease extends to the nasopharynx
 b. History should include the duration of clinical signs, the type and site of involvement of nasal discharge (unilateral or bilateral)
 2. Physical examination
 a. Sedation or anesthesia is usually required
 b. Evaluate for asymmetry of the face, palate, or eyes, areas of pain, patency of the nasal passages, and damaged teeth
 3. Laboratory testing
 a. Complete blood cell count (CBC), serum biochemical profile, and coagulation tests are warranted when a systemic disease is suspected
 b. Serologic tests may be used in the diagnosis of mycotic rhinitis, but false-negative results are common
 4. Imaging
 a. Skull radiography requires general anesthesia. Radiographic views include open-mouth ventrodorsal, occlusal, rostral-caudal frontal skyline, lateral, and oblique
 b. Skull and nasal computed tomography (CT) may be used to delineate the extent of a mass, bone lysis, and accumulation of fluids
 c. Magnetic resonance imaging (MRI) may be used for better definition of brain involvement
 5. Nasal flushing for cytology and biopsy
 a. Aggressive nasal flushing is required to yield sufficient tissue material
 b. Submit samples for cytology and histopathology
 6. Rhinoscopy
 a. Requires general anesthesia
 b. Allows visualization of mucosal lesions, masses, or foreign bodies
 c. Samples for histopathology, cytology, culture, and sensitivity can be obtained with direct visualization
 7. Surgical biopsy may be obtained by exploratory rhinotomy
 B. Laryngeal diseases
 1. History usually includes slowly progressive signs, such as change of voice and inspiratory stridor. Cyanosis and syncope may occur with laryngeal obstruction
 2. Physical examination
 a. Auscultation can detect upper respiratory inspiratory stridor
 b. Palpation of the laryngeal area may detect pain, or asymmetry
 3. Laryngoscopy and bronchoscopy
 a. Evaluate pharyngeal structures, soft palate, and laryngeal movement with the patient under light anesthesia
 b. Endoscopic biopsy, aspiration, or brush cytology may be performed
 4. Diagnostic imaging
 a. Laryngeal radiography may reveal elongated soft palate, fractures, or emphysema
 b. Ultrasonography may demonstrate laryngeal paralysis
 5. Electromyography
 a. Neuromuscular, immune-mediated, and hypothyroidism-related laryngeal disorders may be associated with abnormal studies of the laryngeal muscles
 b. Histopathology may be helpful in the diagnosis of masses or polyneuropathy
 C. Tracheal diseases
 1. History
 a. Chronic, nonproductive, “honking” cough is a typical sign
 b. Inspiratory dyspnea may be present with cervical tracheal collapse and expiratory dyspnea with intrathoracic collapse
 2. Physical examination
 a. Tracheal palpation may produce cough and detect sharp tracheal edges
 b. Perform cardiac examination and auscultate the entire respiratory tract to differentiate the cough from other causes such as cardiac or lower respiratory disorders
 3. Radiography
 a. Both inspiratory and expiratory radiographs may be required to demonstrate collapsing trachea
 b. Fluoroscopy allows dynamic evaluation of the trachea

4. Transtracheal wash (see below)
5. Tracheoscopy may be helpful to visualize tracheal collapse, parasitic granulomas, foreign bodies, or neoplasia

II. Bronchopulmonary and pleural diseases
A. History
1. Typical signs include coughing, tachypnea, dyspnea, and exercise intolerance
2. Determine the duration of signs, the quality of the cough (productive or nonproductive), the time of day of the cough (cardiac cough is usually nocturnal), travel history (infectious diseases), and the presence of other signs (systemic disease)

B. Physical examination
1. Observe the pattern of breathing: Slow, deep breathing with inspiratory difficulty may indicate obstructive upper airway disease; short, shallow breathing may be associated with restrictive disease
2. Thoracic auscultation may reveal adventitious sounds, such as crackles (small airway or parenchymal disease), rhonchi (airway disease or exudate), and wheezes (airway obstruction)
3. Thoracic percussion may yield dull resonance (fluid or mass lesions within the pleural space or lung) or increased resonance (air)

C. Thoracic imaging
1. Determine the type of pattern present (interstitial, alveolar, bronchial, or vascular) and distribution of the lesions (localized or diffuse; cranial or caudal; and ventral, dorsal, or hilar)
2. Thoracic ultrasound may be helpful for detection of small amounts of fluid, consolidated areas of lung and mediastinal masses
3. CT may detect smaller pulmonary and pleural lesions

D. CBC and serum chemistry
1. CBC findings may include leukocytosis (inflammation, infection), eosinophilia (parasitic or allergic disease), polycythemia (chronic hypoxemia), or nucleated red blood cells (acute hypoxemia)
2. Serum biochemistry findings may indicate the presence of systemic disease

E. Arterial blood gas (ABG)
1. An arterial blood sample is usually drawn from dorsal pedal artery or femoral artery
2. ABG analysis evaluates the animal's ability to oxygenate arterial blood. In the normal patient breathing room air, the partial pressure of oxygen should be >95 mm Hg. Elevations in CO_2 indicate ventilatory failure

F. Bronchoscopy allows direct visualization of the lower airway

G. Airway wash
1. Warm sterile saline is instilled in the lower respiratory tract and then retrieved. Samples are submitted for cytology and culture and sensitivity analyses
2. Transtracheal wash is performed in larger dogs. A through-the-needle catheter is inserted percutaneously under local anesthesia between the tracheal rings or through the cricothyroid membrane and then advanced into the lower airway
3. Endotracheal wash is performed in cats and small dogs. A catheter is inserted through a sterile endotracheal tube and then advanced into the lower airway
4. Bronchoalveolar lavage (BAL) may be performed during bronchoscopy and allows retrieving airway fluid sample from the lower airways

H. Lung biopsy
1. Indicated when the cause of a diffuse lung disease cannot be determined by less invasive methods
2. May be obtained by fine-needle aspiration, during bronchoscopy, using ultrasound or CT guidance, during thoracotomy (keyhole biopsy), or during thoracosopy

I. Thoracocentesis is performed to obtain fluid for analysis for diagnosis of pleural effusion

NASAL CAVITY AND SINUSES

I. Congenital diseases
A. Primary ciliary dyskinesia
1. Uncoordinated and ineffective ciliary function resulting in rhinitis, bronchitis, bronchiectasis, and bronchopneumonia
2. When associated with situs inversus, the clinical syndrome is known as Kartagener syndrome
3. Clinical signs include nasal discharge and coughing that begin at an early age
4. Diagnosis
a. Measuring the velocity of mucus clearance by using a drop of labeled macroaggregated albumin
b. Analysis of cilia by electron microscopy
5. Treatment is based on antibiotic therapy to treat secondary infections
6. Prognosis is guarded

B. Cleft palate (see Chapter 27)

II. Rhinitis and sinusitis of infectious origin
A. Causes
1. Dogs: Parainfluenza, distemper, adenovirus-2, *Bordetella bronchiseptica, Aspergillus flavum, Penicillium* spp., *Rhinosporidium seeberi*
2. Cats: Herpesvirus, calicivirus, *Chlamydia psittaci, Bordetella bronchiseptica, Cryptococcus neoformans*
3. Chronic rhinitis is often associated with another predisposing problem such as immunosuppression, foreign body, or tumor

B. History
1. Acute viral rhinitis is usually self-limiting unless immunosuppression is present
2. Primary bacterial rhinitis occurs with *Bordetella bronchiseptica* infection. Other bacterial nasal infections are usually secondary

3. *Aspergillus flavus* is a normal inhabitant of the nasal cavity, but it may invade respiratory epithelium in dogs with altered immunity or mucosal injury

C. Clinical signs
1. Typical signs include sneezing and nasal discharge. Gagging or retching may occur due to postnasal drip
2. Reversed sneezing may occur with nasopharyngeal involvement

D. Diagnosis
1. Dogs
 a. Serologic tests for aspergillosis and polymerase chain reaction (PCR) for *Bartonella*
 b. Imaging includes open-mouth radiographs or CT of the nasal cavity
 c. Rhinoscopy may reveal a foreign body, a mass lesion, turbinate destruction, secretions
 d. Histologic examination of nasal tissue is required for detection of hyphae of *Aspergillus*. Culture may be positive in normal dogs
 e. Bacterial culture of mucosal biopsies may be more indicative of infection. Culture of nasal secretions may be positive in normal dogs
2. Cats
 a. Serologic tests for feline immunodeficiency virus, feline leukemia virus, and *Cryptococcus*
 b. Cytology from a nasal swab for detection of *Cryptococcus*
 c. Tests for herpesvirus diagnosis (immunofluorescence, PCR).
 d. If empiric treatment fails, perform imaging, rhinoscopy, and biopsy

E. Treatment
1. Viral
 a. Supportive care and broad-spectrum antibiotic treatment
 b. Lysine may be tried if herpesvirus infection is suspected
2. Bacterial
 a. Doxycycline is effective against *B. bronchiseptica* or *Bartonella* infections, and clindamycin has some efficacy against *Mycoplasma*
 b. Treat underlying disorder (e.g., foreign body, tooth root abscess)
3. Fungal
 a. *Aspergillus flavus* and *Penicillium* spp. are most commonly treated with nasal tubes for intranasal administration of clotrimazole or eniconazole. Oral therapy with ketoconazole, itraconazole, or thiabendazole is generally less effective
 b. *Rhinosporidium* granulomas can be treated by surgical extraction
 c. *Cryptococcus neoformans* infection is treated with fluconazole, itraconazole, ketoconazole, or amphotericin B (alone or in combination with flucytosine)

III. Nasal parasites
A. Cuterebra, *Eucoleus boehmi* (nasal nematode), *Pneumonyssus caninum* (nasal mite)
B. Clinical signs include sneezing, nasal discharge, and reversed sneezing
C. Diagnosis is typically accomplished by direct visualization. *E. boehmi* is diagnosed by mucosal biopsy or identification of the ova on a fecal examination
D. Treatment is by manual removal of large parasites or by treatment with oral ivermectin.

IV. Allergic rhinitis
A. Presumed to occur in dogs and cats
B. Immunoglobulin E based rhinitis has not been demonstrated yet

V. Nasopharyngeal polyps
A. Inflammatory masses that arise from the epithelium of the nasopharynx. Commonly occur in cats
B. Voice change is a common early sign. Gagging may also occur
C. Otoscopic examination may reveal discharge and polypoid masses within the external ear canal. Oropharyngeal examination may demonstrate the polyp by retraction of the soft palate
D. Skull radiographs or CT may reveal increased density of one of the bullae or cranial to the pharynx
E. Treatment
1. Removal of the mass by traction
2. Ventral bulla osteotomy is indicated for removal of the inflammatory tissue when the middle ear is involved

VI. Foreign body
A. Common in young dogs; grass awns and other plant material especially common
B. Signs include sneezing and nasal discharge
C. Plants material is usually not visualized on radiographs
D. Rhinoscopy allows visualization and removal of the foreign body in most cases

VII. Neoplasms of the nasal cavity and paranasal sinuses
A. In dogs, carcinomas are most common, followed by sarcomas. Transmissible venereal tumors are uncommon but should be considered in endemic areas. Plasma cell tumors, mast cell tumors, and benign tumors occur rarely
B. In cats, nasal and paranasal lymphomas are most common, followed by adenocarcinoma and squamous cell carcinoma. Benign nasopharyngeal inflammatory polyps are common
C. Malignant nasal tumors usually are locally invasive, with metastasis occurring late in the course of the disease
D. Clinical signs
1. Nasal tumors are more common in older animals. Dolichocephalic and large-breed dogs are predisposed. There is no sex predilection
2. Common clinical signs include sneezing, nasal discharge, and epistaxis. Facial deformity occurs most commonly with skeletal neoplasms. Seizures, blindness, and behavioral changes may result from invasion to the central nervous system

E. Diagnosis
1. Radiography of the nasal cavity and paranasal sinuses may demonstrate loss of trabecular pattern, increase in soft tissue density, and septal destruction. Thoracic radiographs may indicate the presence of distant metastasis
2. CT and MRI are useful for evaluating the extent of the tumor
3. Biopsy for histopathologic examination is required for diagnosis and may be acquired by a blind procedure, rhinoscopy, or rhinotomy

F. Treatment
1. Radiation therapy has been shown to increase survival time in dogs and cats
2. Surgical cytoreduction in combination with radiation is rarely indicated for malignant tumors. Surgery is the treatment of choice for nasal polyps
3. Chemotherapy is indicated for the treatment of lymphoma and transmissible venereal tumor

UPPER AIRWAY DISORDERS

I. Brachycephalic syndrome
A. Consists of congenital disorders including stenotic nares, elongated soft palate, and tracheal hypoplasia (English bulldogs) and consequently, laryngeal saccules eversion
B. Signs include characteristic stretor and snoring and occasionally exercise intolerance
C. On physical examination stenotic nares may be evident
D. Oropharyngeal examination may reveal soft palate overlapping on the epiglottis. Everted laryngeal saccules may be seen as oval mucosal masses lateral to vocal folds
E. Treatment
1. Nasal wedge resection
2. Staphylectomy
3. Laryngeal sacculectomy

II. Laryngeal collapse
A. Most commonly results from brachycephalic syndrome
B. Signs include stretor or stridor, dyspnea, and occasionally exercise intolerance
C. Oropharyngeal examination reveals apposition or overlap of the arytenoids cartilages
D. Treatment
1. Treat predisposing factors (brachycephalic syndrome)
2. If signs persist permanent tracheostomy may be necessary

III. Laryngeal paralysis
A. Diagnosed primarily in old, large-breed dogs
B. Interrupted innervation of the larynx results in failure of the arytenoids cartilages to abduct during inspiration
C. Congenital in some breeds (e.g., the Bouvier des Flandres). Might be associated with hypothyroidism or polyneuropathies. Many cases are idiopathic
D. Clinical signs include stridor, voice change, and intermittent dyspnea, exacerbated by exercise, stress, or high environmental temperature. Hyperthermia may occur
E. Oropharyngeal examination under light anesthesia confirms the diagnosis. The arytenoids cartilages are unable to abduct during inspiration. Laryngeal edema may be present
F. Treatment is by arytenoid lateralization

IV. Laryngeal neoplasms
A. Generally rare in dogs and cats. Malignant tumors are more common
B. Laryngeal tumors may be primary (e.g., squamous cell carcinoma, lymphoma, chondrosarcoma) or metastatic (e.g., thyroid carcinoma)
C. The most common clinical sign is inspiratory dyspnea
D. Diagnosis
1. Radiography may demonstrate laryngeal distortion
2. Laryngoscopic evaluation may reveal a mass
3. Diagnosis in confirmed by biopsy and histopathology
E. Treatment
1. Surgical excision may be curative for benign tumors
2. Radiotherapy and chemotherapy may be beneficial for some tumors

V. Tracheal stenosis
A. Usually results from traumatic tracheal injury (e.g., bite wounds, intubation)
B. Signs include dyspnea and less commonly cough
C. Thoracic radiographs demonstrate focal reduction of the tracheal lumen diameter
D. Tracheoscopy is useful for assessing the location and severity of the stenosis
E. Treatment is by removal of the stenotic segment by tracheal resection and anastamosis

VI. Tracheal collapse
A. Causes
1. In dogs, abnormalities in chondrogenesis (congenital, inherited, or related to dietary deficiencies) result in decreased turgidity of the tracheal ring. Collapse may be found at rest or may be dynamic, with cervical collapse found on inspiration and intrathoracic collapse on expiration. Collapse of smaller airways may be also present
2. In cats, obstructive upper airway masses may cause tracheal collapse

B. Pathophysiology
1. The trachea usually collapses in a dorsoventral orientation, causing trauma to the epithelial surface, mucus production, and perpetuation of cough
2. Reduction in airway radius increases resistance to airflow and additional airway injury

C. Clinical Signs
1. Small-breed dogs are typically affected with tracheal collapse
2. History
a. Long-term history of chronic, intermittent honking cough
b. May be associated with gagging, retching, or syncope
c. May exacerbate due to stress, heat, humidity, weight gain, and endotracheal intubation

3. Physical examination
 a. Gentle tracheal palpation may induce cough. Sharp edges of the trachea may be palpated at the collapsed area
 b. High-pitched inspiratory sounds are heard over a narrowed cervical trachea
 c. An end-expiratory snap may be heard over the thorax with intrathoracic collapse

D. Diagnosis
1. Radiography
 a. Inspiratory and expiratory views are recommended to evaluate for cervical or intrathoracic collapse. False-negative and false-positive are common
 b. Fluoroscopy with induction of cough may be useful
2. Bronchoscopy can confirm the presence of collapse, identify passive or dynamic collapse, and determine the extent and grade of the disease
3. Airway sampling should be obtained by tracheal wash or tracheobronchoscopy for cytology and culture (including *Mycoplasma* spp.) to identify conditions that may worsen the signs

E. Treatment
1. General: Weight reduction is beneficial in most cases. Limit exposure to environmental stressors. A harness should be used in place of a collar
2. Antitussives: Opiates (e.g., hydrocodone, butorphanol) are most effective
3. Bronchodilators: May be beneficial when there is evidence of concurrent small airway disease
4. Antiinflammatory drugs: A short course of prednisone may be required when tracheal inflammation is present
5. Antibiotics: Bacterial infection is uncommon. When suspected, doxycycline and enrofloxacin are good first choices pending culture results
6. Surgical stabilization has been successful in reducing clinical signs in dogs with severe tracheal collapse that failed to respond to medical management. Serious complications occur occasionally

F. Prognosis: Irreversible disease. The goals of treatment are to minimize clinical signs

VII. Other causes of tracheal obstruction
A. Causes
1. Intraluminal foreign bodies rarely cause complete obstruction
2. Extraluminal compression of the trachea may be caused by compression from extraluminal masses such as thyroid carcinoma, hilar lymphadenopathy, mediastinal masses, or atrial enlargement
3. Primary tracheal neoplasia is uncommon in dogs and cats
 a. Dogs: Osteosarcoma, chondrosarcoma, leiomyoma, mast cell tumor, adenocarcinoma, and squamous cell carcinoma
 b. Cats: Lymphoma and adenocarcinoma

B. Signs may include dyspnea and cough
C. Thoracic radiography or CT may demonstrate foreign bodies or soft tissue density within the tracheal lumen or extraluminal masses
D. Treatment
1. Foreign body can often be removed with an endoscope
2. Tracheal resection and anastamosis is required for tracheal neoplasia removal

BRONCHOPULMONARY DISEASES

I. Infectious tracheobronchitis (ITB) (see Chapter 18, Infectious Diseases)

II. Canine chronic bronchitis
A. Causes and pathophysiology
1. Cause is unknown. Immunologic stimulation, chronic mucosal irritation from air pollution, or chronic aspiration of gastrointestinal (GI) content may cause chronic inflammation
2. Neutrophilic infiltration of the airway induces epithelial injury, mucus accumulation, and airway obstruction

B. History and clinical signs
1. Middle-aged to older dogs, often overweight. Small- and large-breeds are affected
2. Presence of chronic cough, which may be described as dry hacking or moist
3. The dog is typically not systemically ill
4. On physical examination, slow, deep respiratory pattern is typical. Prolonged expiration with an expiratory push may be apparent in severe cases. Expiratory wheezes and coarse crackles may be evident on auscultation. Respiratory sinus arrhythmia is usually present in dogs with chronic bronchitis and may be helpful to rule out congestive heart failure (CHF) as the primary cause for the cough

C. Diagnosis
1. The diagnosis is based on the history, clinical findings, thoracic radiographs, and airway sampling to rule out other pulmonary causes of cough
2. Generalized peribronchial infiltrates, characterized by “doughnuts” or “tram lines,” are typical findings. Normal thoracic radiographs are common and do not rule out bronchitis (Figure 25-1)
3. Bronchoscopy is useful in the diagnosis and typically shows airway hyperemia and a roughened appearance to the mucosa. Increased mucus in the airways is present in most cases. In some long-standing cases, nodular proliferations of the mucosa are apparent
4. Airway sampling should be obtained through endotracheal or transtracheal wash or with bronchoscopy for cytology evaluation and culture
5. Typical findings on cytologic evaluation include increased percentage of nondegenerative neutrophils and Curschmann’s spirals (airway mucus)

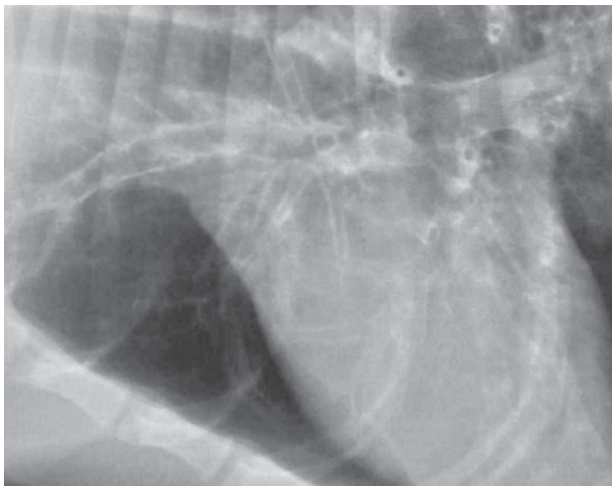


Figure 25-1 Lateral thoracic radiograph of a middle-aged dog with chronic cough attributable to bronchitis. A striking bronchial pattern well seen overlying the heart is present as a result of thickened bronchial walls. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology*, 5th ed. St Louis, 2007, Saunders.)

6. Airway samples should be submitted to aerobic culture and *Mycoplasma* culture. The presence of oral contaminants on cytology (e.g., squamous cells or *Simonsiella* bacteria) makes a positive culture result of questionable importance

D. Treatment
 1. General treatment includes weight reduction for overweight dogs, environmental control (e.g., smoke, dust, heat) when possible, and airway humidification (steam inhalation or nebulization)
 2. Antiinflammatory drugs are required to decrease airway inflammation. Prednisone is usually given at a dose of 0.5 to 1.0 mg/kg every 12 hours for 5 to 7 days, and then the dose is tailored according to the response. Infection should be ruled out before prednisone is administered
 3. Bronchodilators may be helpful in reducing clinical signs through reduction of work of breathing and stimulation of mucociliary clearance. β-agonists (e.g., terbutaline, albuterol) are more effective compared with theophylline. The dose of theophylline should be reduced if administered with enrofloxacin because enrofloxacin inhibits its metabolism
 4. Antitussives should be used to suppress cough if no infection is present and most of the inflammation and secretions are resolved
 5. Antibiotics are warranted when secondary infection has been documented. Doxycycline is a good first choice pending culture results. However, infection is not a common component of the disease

E. Prognosis
 1. This is a chronic disease
 2. Goals of therapy are to control the degree of inflammation and clinical signs and early diagnosis and treatment of secondary infections

III. Bronchiectasis

A. Cause and pathophysiology
 1. Irreversible dilation of the airways typically accompanied by suppuration
 2. Possible causes include chronic inflammation (e.g., bronchitis, foreign body), smoke inhalation, and primary ciliary dyskinesia
 3. Dilated airways lack normal mucociliary clearance and trap secretions distally

B. Clinical signs
 1. Dogs are primarily affected. Rarely occurs in cats
 2. History usually includes chronic productive cough, failure to respond to standard therapy, and sometimes hemoptysis
 3. Physical examination may reveal fever and abnormal lung sounds, such as crackles and increased bronchial sounds. Normal lung sounds may be absent with lung consolidation

C. Diagnosis
 1. CBC may indicate inflammation
 2. Thoracic radiography may show airway dilation and lung consolidation but is not sensitive
 3. CT may demonstrate increased airway space with thickened airway wall and is more sensitive
 4. Bronchoscopy can be very useful for the diagnosis and may show the dilated airway, reddening of the mucosa, and accumulation of mucus or pus
 5. Cytologic evaluation of BAL fluids typically shows increased number of neutrophils and sometimes intracellular bacteria. Both aerobic and anaerobic cultures should be obtained
 6. Electron microscopy on biopsies of tracheal epithelium is used to diagnose ciliary dyskinesia

D. Treatment
 1. General therapy with nebulization, chest coupage, and postural drainage may assist in the removal of secretions from the airways
 2. Antibiotic treatment should be based on culture and sensitivity results. Long-term treatment may be required
 3. Lung lobectomy should be considered in cases of focal bronchiectasis

E. Prognosis: There is continued increased risk for infection in most cases

IV. Feline bronchial disease

A. Cause and pathophysiology
 1. An inflammatory process within the airways results in mucosal edema, increased bronchial mucus, and reversible bronchoconstriction
 2. The cause is not identified in most cases. Associations with *Mycoplasma*, *Aelurostrongylus abstrusus*, and *Dirofilaria immitis* have been proposed in some affected cats
 3. Cats with bronchial disease are thought to have hyper-responsive airways

B. Clinical signs
 1. There is no gender or age predilection. Siamese cats may be more sensitive
 2. A cat may present with a long-term history of coughing, gagging, and lethargy or with an acute episode of respiratory distress and cyanosis

3. On physical examination, prolonged expiration and decreased thoracic compliance may be evident in some cats. Thoracic auscultation may reveal wheezes or crackles. Open-mouthed breathing and cyanosis occur in an acute episode

C. Diagnosis
1. CBC may reveal eosinophilia in some cats. Fecal examination to detect parasitic infection and heartworm testing are indicated in endemic areas
2. Typical thoracic radiographic findings include an interstitial peribronchial pattern with "doughnuts" and "tram lines." Additional findings may include lung hyperinflation, patchy alveolar pattern, or lung consolidation. Normal radiographs do not rule out the diagnosis
3. Bronchoscopy can reveal mucus accumulation or plugging and nodular irregularities
4. Cytologic evaluation of airway fluids obtained by endotracheal washing or bronchoscopy can include eosinophilic, neutrophilic, or mixed inflammatory responses. (Normal cats may have as much as 25% eosinophils on cytology)
5. Culture of airway fluids is warranted when there is evidence of infection on cytology. Cultures of many healthy cats are positive for *Mycoplasma* spp.
6. Pulmonary function tests indicate higher airway resistance

D. Treatment
1. Emergency therapy
 a. Minimize stress
 b. Administer a bronchodilator (e.g., terbutaline, albuterol) subcutaneously or through an inhaler
 c. If there is no immediate improvement, administer short-acting parenteral corticosteroids
2. Chronic management
 a. Antiinflammatory drugs are the mainstay of therapy. A high dose of prednisolone is given for several days and then tapered according to the clinical response. Alternatively, long-acting steroid injections or inhaled steroids may be used. Treatment may be discontinued in 50% of the cats
 b. Oral bronchodilators (e.g., terbutaline, theophylline) may help to control clinical signs and decrease the dosage of corticosteroids required
 c. Control of environmental triggers (e.g., smoke, dust) may be beneficial in some cases
 d. β-blocker drugs can cause bronchoconstriction and should be avoided

E. Prognosis: The disease can be chronic with either persistent signs or recurrent episodes

V. Interstitial lung disease

A. Causes and pathophysiology
1. The cause is unknown and probably multifactorial. Genetic factors may play a role
2. Exposure to a variety of insults can initiate a chronic progressive inflammatory process, which may lead to diffusion impairment, lung fibrosis, and eventually end-stage restrictive lung disease

B. Clinical signs
1. Small-breed dogs, especially West Highland white terriers may be at increased risk
2. History typically includes shortness of breath and exercise intolerance. Episodes of syncope may occur
3. Physical examination may reveal tachypnea and sometimes cyanosis. Typical findings on auscultation are diffuse inspiratory crackles. Split-second heart sound may be evident when pulmonary hypertension develops

C. Diagnosis
1. Thoracic radiographs usually show diffuse interstitial pattern but may be normal
2. BAL cytology shows increased percentage of neutrophils but no mucus. Cultures are negative
3. Pathology of lung tissue shows interstitial fibrosis in cats and increased collagen in West Highland white terriers, with no inflammation

D. Treatment
1. Decrease exposure to possible triggers and control weight
2. Prednisone at antiinflammatory to immunosuppressive doses may result in improvement
3. A trial therapy with bronchodilators may be considered

E. Prognosis is guarded

VI. Bronchopneumonia of infectious origin

A. Causes
1. Pulmonary infections are common. Most cases are of bacterial origin
2. Infection is typically by inhalation. The hematogenous route is less common
3. Predisposition for bacterial pneumonia is present in many cases, including ITB, chronic bronchitis, aspiration of oral or GI content from vomiting or laryngeal paralysis, immunosuppression, foreign body

B. Clinical signs
1. Typical signs include tachypnea, respiratory distress, productive cough, and fever. Mucopurulent nasal discharge may be present
2. Auscultation reveals increased bronchial sounds and crackles

C. Diagnosis
1. Typical findings of bacterial bronchopneumonia on thoracic radiographs include alveolar pattern with air bronchogram in a craniоventral distribution. Dorsocaudal pulmonary infiltrates are more likely to be caused by atypical microorganisms (mycoplasmas, fungal infections, mycobacteria) or hematogenous pneumonia
2. CBC may reveal leukocytosis with a left shift or neutropenia

3. Cytology of airway lavage demonstrates increased numbers of degenerative neutrophils, often with intracellular bacteria. Culture is typically positive

D. Treatment
1. Antibiotic treatment should be based on culture and sensitivity results
2. Bronchodilator therapy (e.g., theophylline) may be beneficial
3. Supportive therapy includes intravenous (IV) fluids, airway humidification, and coupage

VII. Pulmonary infiltrates with eosinophils

A. Causes and pathophysiology
1. Lungworms, heartworms, larval migration, fungal infections and hypereosinophilic syndrome may be associated with accumulation of eosinophils in the lungs. Many cases are idiopathic
2. Eosinophils activation cause epithelial injury, leading to increased mucus and increased resistance to airflow

B. Clinical signs
1. History usually includes exercise intolerance, cough, and sometimes hemoptysis
2. Thoracic auscultation may reveal increased bronchial sounds and diffuse coarse crackles

C. Diagnosis
1. CBC may show leukocytosis with eosinophilia and basophilia
2. Tests for heartworm, lungworm, and parasitic infections should be performed
3. Thoracic radiographs typically show a mixed infiltrative pattern
4. Bronchoscopy reveals hyperemic airways, with mucus. Polypoid proliferations on the epithelium and bronchiectasis may be seen
5. Cytology of airway fluid reveals increased percentage of eosinophils

D. Treatment
1. Removal of possible allergens and empiric anthelmintic treatment are warranted
2. Immunosuppression glucocorticoid therapy is required in most cases

VIII. Granulomatous pulmonary diseases

A. Causes
1. Commonly associated with systemic fungal infections in endemic regions
2. Noninfectious forms include eosinophilic pulmonary granulomatosis, which is associated with heartworm infection and pulmonary lymphomatoid granulomatosis, which is probably a neoplastic condition

B. Clinical signs
1. Any age or breed may be affected
2. History includes chronic respiratory distress, cough, and systemic signs
3. Thoracic auscultation reveals wheezes and coarse crackles

C. Diagnosis
1. CBC typically shows leukocytosis. Hyperglobulinemia may be present. Thoracic radiographs reveal nodular pattern with hilar lymphadenopathy
2. Cytologic examination of BAL commonly reveals eosinophilic inflammation. Fungal elements may be found with mycotic infections
3. Definitive diagnosis of noninfectious forms requires lung histopathology

D. Treatment
1. Treat pulmonary mycosis or heartworm infection when diagnosed
2. The noninfectious forms require immunosuppressive therapy, including prednisone or a combination of cytotoxic drugs

E. Prognosis is guarded

IX. Noncardiogenic pulmonary edema

A. Causes and pathophysiology
1. High-pressure edema is caused by overexpansion of plasma volume or decreased oncotic pressure that leads to fluid accumulation in the lung
2. Permeability edema is caused by damage to the alveolocapillary membrane that allows protein-rich fluid to flood the alveoli (e.g., aspiration pneumonia, smoke inhalation, sepsis, and anaphylaxis)

B. Clinical signs
1. History includes signs of tachypnea, respiratory distress, and cyanosis
2. Thoracic auscultation reveals fine crackles

C. Diagnosis
1. Thoracic radiographs show patchy interstitial and alveolar pattern in the periphery and caudodorsal lung lobes

D. Treatment
1. Treat the primary disease
2. There is no specific therapy. Supportive treatment may include: Oxygen therapy, sedation, and mechanical ventilation. IV fluids and diuretics should be used with caution

X. Pulmonary thromboembolism

A. Underlying causes include heartworm disease, pulmonary neoplasia, septicemia, amyloidosis, hyperadrenocorticism, and immune-mediated hemolysis

B. Clinical signs include dyspnea and right-sided heart failure

C. Radiographic findings include blunted pulmonary arteries and hypovascularity of the affected lung. However, abnormalities may be absent

D. Treatment is based on resolving the underlying cause

XI. Lung contusion

A. Hemorrhage into the pulmonary parenchyma, most often caused by blunt thoracic trauma

B. Clinical signs include acute dyspnea and possibly shock from blood loss

C. Diagnosis
1. Auscultation may reveal crackles over a contused area or decreased lung sounds suggestive of lung consolidation or pleural effusion
2. Thoracic radiographs typically reveal irregular patches of mixed interstitial-alveolar densities. Radiographic changes may be delayed for up to 24 hours

D. Treatment
1. Transfusion of whole blood as indicated
2. Administer oxygen if needed
3. Bronchodilators may improve ventilation
4. Frequent repositioning of a recumbent animal to prevent atelectasis
5. Positive-pressure assisted ventilation may be necessary in severe cases

XII. Lungworms
A. Causes
1. *Aelurostrongylus abstrusus* is a nematode that requires a snail as intermediate host and infects cats when they eat transport hosts (birds, small mammals, reptiles)
2. *Paragonimus kellicotti* infects dogs and cats by their ingestion of an intermediate host (crayfish, aquatic snail) or by a transport host (e.g., raccoon)
3. *Capillaria aerophilia* infects dogs and cats by a direct life cycle
4. *Crenosoma vulpis* infrequently infects dogs
5. *Oslerus osleri* forms granulomas near the tracheal bifurcation. *Filaroides milksi* is a bronchopulmonary parasite, and *Filaroides hirthi* is a lung parasite. These nematodes infect dogs by direct transmission

B. Clinical signs
1. Signs are apparent most often in young animals that are heavily infested
2. Cough is the most common sign

C. Diagnosis
1. CBC may reveal eosinophilia
2. Thoracic radiography findings may include interstitial to granulomatous patterns. Air-filled cystic structures may appear with *Paragonimus* infection
3. Fecal flotation can identify ova (*Capillaria, Paragonimus*) or larva (*Aelurostrongylus, Osleri, Filaroides*). Baermann technique may be required
4. Typical cytology findings of airway lavage include eosinophilic infiltrate. Parasitic ova or larva may be demonstrated

D. Treatment
1. Fenbendazole is the safest antiparasitic drug
2. Adjunctive treatment with prednisolone may be beneficial in cases of severe eosinophilic pulmonary reaction

E. Prognosis is generally good unless severe granulomatous disease has developed

XIII. Other respiratory parasites
A. *Dirofilaria immitis* is found in the pulmonary arteries, causing secondary pulmonary injury (see Chapter 12, Cardiovascular Disorders)
B. *Toxoplasma gondii* may cause pneumonia (see Chapter 18, Infectious Diseases)

XIV. Pulmonary neoplasms
A. Carcinomas (bronchial, bronchoalveolar, or alveolar) are the most common primary lung tumors in dogs. Metastatic rate at the time of diagnosis is high
B. Metastatic pulmonary neoplasms are more common
C. Clinical signs
1. Occur in older animals. Larger dogs may be at increased risk. There is no sex or breed predilection
2. The most common clinical sign is chronic cough. Dyspnea and weight loss may also occur. No signs may be apparent in some cases

D. Diagnosis
1. Thoracic radiography usually reveals a mass lesion. Evaluation of three views (ventrodorsal, right lateral, and left lateral) is recommended. Up to 11% of pulmonary neoplasms might not be detected in survey radiographs. CT or MRI may be useful to detect occult masses
2. Cytologic evaluation of sample obtained by percutaneous transthoracic fine-needle aspiration or airway lavage may detect neoplastic cells in some cases
3. Lung biopsy obtained by bronchoscopy, thoracoscopy, or thoracotomy is usually required to confirm the diagnosis

E. Treatment
1. Surgical excision of solitary masses is the treatment of choice
2. Adjunctive chemotherapy may improve survival in some cases

DISORDERS OF THE THORACIC CAVITY

I. Thoracic wall trauma
A. May be due to blunt or penetrating injuries
B. Pain may lead to hypoventilation because the animal is unwilling to breathe
C. A flail segment may be present when multiple segmental rib fractures produce a free segment of thoracic wall, which moves inward during inspiration and outward during expiration
1. Flail chest segments can initially be stabilized by positioning the animal with the flail side down
2. Surgical stabilization may be required

D. Subcutaneous emphysema can occur with blunt or penetrating trauma. The condition is usually self-limiting; treatment should be directed at the underlying cause

II. Pneumothorax
A. Cause
1. Traumatic pneumothorax is more common. Blunt trauma may cause pulmonary or bronchial rupture and closed pneumothorax. Penetrating trauma through the thoracic wall causes an open pneumothorax
2. Spontaneous pneumothorax is caused by rupture of pulmonary blebs or bullae and is considered primary when there is no evidence of underlying pulmonary disease. Secondary spontaneous pneumothorax is more common and may occur with pulmonary abscesses, emphysema, neoplasia, pneumonia, or parasites

B. Clinical signs
1. Primary spontaneous pneumothorax occurs most frequently in large, deep-chested dogs

2. History of a traumatic event may be present with traumatic pneumothorax. History of previous respiratory signs may be present with secondary spontaneous pneumothorax
3. The animal presents with acute dyspnea, and shallow rapid respiration. Cyanosis may be evident

C. Diagnosis
1. Auscultation may reveal decreased heart and lung sounds. On percussion, the thoracic cavity is hyperresonant
2. Thoracic radiograph findings may include elevation of the heart off the sternum, collapse of the lung lobes and retraction from the chest wall, and a radiolucent area of free air (Figure 25-2)

D. Treatment
1. Open chest wounds should be covered immediately
2. Thoracocentesis should be performed to stabilize a dyspneic animal
3. Thoracostomy tube may be required if air accumulates rapidly
4. Once the animal is stable, an underlying cause for spontaneous pneumothorax should be considered

III. Pleural effusion

A. An abnormal accumulation of fluid within the pleural space. It occurs when fluid formation is increased (e.g., increased capillary hydrostatic pressure), fluid absorption is decreased (e.g., decreased colloidal osmotic pressure), or pleural capillary permeability is increased (e.g., pleural inflammation)

B. Clinical signs
1. Dyspnea and exercise intolerance are the most common signs
2. The animal may prefer sitting or standing with extended head and abducted elbows

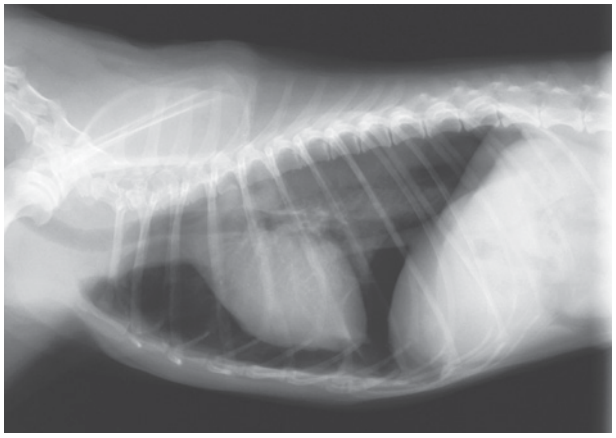


Figure 25-2 Lateral radiograph of a dog with pneumothorax. Note the apparent elevation of the heart from the sternum. (From Ettinger SJ, Feldman EC, editors. *Textbook of Veterinary Internal Medicine*, 6th ed. St Louis, 2005, Saunders.)

C. Diagnosis
1. Physical examination
a. Thoracic auscultation reveals muffled heart and lung sounds ventrally
b. On percussion, the thorax sounds dull and hyporesonant
2. Thoracic radiography usually confirms pleural effusion. Signs include separation of the lung lobes from the parietal pleura and sternum and obscuring of the cardiac and diaphragmatic shadows
3. Thoracocentesis provides pleural fluids for analysis and therapeutic drainage. The fluid may be classified as transudate, modified transudate, nonseptic exudate, septic exudate, chylous effusion, or hemorrhage
4. Laboratory evaluation may provide useful information on the underlying cause
5. Ultrasonography of the thorax may confirm the presence of pleural fluids and help in the diagnosis of some of the primary causes (e.g., mediastinal mass, diaphragmatic hernia, cardiac disease)

D. Pyothorax
1. Causes
a. Accumulation of purulent exudate within the pleural space as a result of intrapleural bacterial infection (septic pleuritis) or, rarely, mycotic infection
b. Mixed bacterial infections are most common, but entire anaerobic bacterial and fungal infections may also occur
c. The source of infection in not identified in most cases. Possible sources include penetrating chest wounds, perforations of mediastinal structures (i.e., esophagus, trachea, bronchi), migrating foreign bodies (e.g., grass awns), direct extension from the lung in bacterial pneumonia, and hematogenic spread from distant infection
2. Clinical signs may include fever, depression, and anorexia, in addition to dyspnea
3. Diagnosis
a. Hematologic findings typically include neutrophilia with left shift and neutrophilic toxicity. Neutropenia with a degenerative left shift may occur in severe cases
b. Thoracic radiography findings are typical of pleural effusion
c. Pleural fluid analysis reveals an opaque fluid with protein concentration greater than 4.5 g/dL and nuclear cell count greater than 50,000/μL (mostly degenerated neutrophils). Cytologic examination of the fluid reveals intracellular bacteria. Culture for aerobic and anaerobic bacteria should be performed
4. Treatment
a. Antibiotic treatment is based on culture and sensitivity results and should last for at least 6 weeks
b. Place thoracic tube to allow intermittent drainage and lavage of the pleural cavity

5. Complications include pleural adhesion and pulmonary abscess formation and require thoracotomy to break the adhesions and remove diseased tissue

E. Chylothorax
1. Causes
 a. Accumulation of chyle in the pleural space
 b. The cause is unknown in most cases. Possible causes include lymphangiectasia of intrathoracic lymphatics, traumatic rupture of the thoracic duct, intrathoracic neoplasia, cardiac disease, diaphragmatic hernia, lung lobe torsion, and vena caval thromboembolism
 c. Some breeds (Afghan hound, Shiba Inu, Siamese and Himalayan cats) are predisposed to idiopathic chylothorax
2. Clinical signs often include coughing in addition to typical signs of pleural effusion
3. Diagnosis
 a. Chylous effusion is characterized by higher triglyceride and lower or equal cholesterol concentrations compared with the serum. Pleural fluid cholesterol-to-triglyceride ratio is less than 1
 b. Cytologic examination of pleural fluids reveals mostly small lymphocytes
 c. An underlying cause should be considered
4. Medical treatment
 a. Treat any underlying cause. Traumatic thoracic duct rupture is treated by periodic pleural drainage and rest
 b. A fat-restricted diet supplemented with medium-chain triglycerides that has been recommended in the past is not effective clinically
 c. Administration of rutin may be beneficial, but clinical results are inconsistent
5. Surgical treatment is indicated if no underlying medically treatable cause is found
 a. Ligation of the thoracic duct at the level of the diaphragm. Partial pericardectomy may improve the success rate of the procedure
 b. Pleuroperitoneal shunting may be performed in refractory cases
 c. Pleurodesis (using tetracycline or sterile talc) may be palliative in some cases
6. Complications include development of chronic fibrosing pleuritis. Surgical decortication (removal of the layer of fibrin and fibrotic reaction covering the visceral pleura) is indicated to avoid excessive pleural fibrosis

F. Hemothorax
1. Accumulation of blood within the pleural space may be caused by thoracic trauma, ruptured thoracic neoplasia, disorders of hemostasis, or lung lobe torsion
2. Clinical signs include shock due to blood loss and dyspnea due to pleural effusion
3. Diagnosis
 a. Thoracic auscultation and percussion are typical for pleural effusion
 b. Thoracentesis yields nonclotting blood
4. Treatment
 a. Treat hypovolemic shock with IV fluids or blood transfusion
 b. Perform thoracentesis to relieve respiratory distress
 c. Consider exploratory thoracotomy for animals that fail to stabilize

G. Feline infectious peritonitis (see Chapter 18, Infectious Diseases)

H. Congestive heart failure (CHF) (see Chapter 12, Cardiovascular Disorders)

I. Lung-lobe torsion
1. The mechanism is unknown. Lung-lobe torsion may be the cause or the result of the pleural effusion
2. Clinical signs are typical of pleural effusion
3. Diagnosis
 a. Thoracic radiography after thoracocentesis reveals a consolidated lung lobe
 b. Pleural fluid analysis may vary
 c. Ultrasonography may be helpful to identify lung-lobe torsion
 d. Confirmation of the diagnosis requires thoracotomy in many cases
4. Treatment is by lung lobectomy

J. Thymic branchial cysts
1. Multicystic masses in the cranial mediastinum. Develop from vestiges of the fetal branchial arch system. Usually cause pleural effusion
2. Pleural fluid may be modified transudate or nonseptic exudates
3. Treatment is by surgical resection

K. Diaphragmatic hernia
1. May be complicated by pleural effusion, which is usually a modified transudate, but may be blood or chyle in some cases
2. See soft tissue surgery section for further discussion

L. Pancreatitis-associated effusion
1. Mild transient pleural effusion may occur with acute pancreatitis
2. The pathogenesis is not fully understood
3. Usually self-limiting

M. Pulmonary thromboembolism
1. Pleural effusion may occur whenever pulmonary thromboembolism is extensive enough to produce infarction and ischemic necrosis of the lung
2. The effusion is usually a modified transudate or nonseptic exudate
3. Treatment involves managing the underlying cause and drainage of the pleural effusion

N. Intrathoracic neoplasia
1. Neoplastic pleural effusion is caused by hemolymphatic obstruction. Common causes include mediastinal lymphoma and thymoma, primary and metastatic pulmonary neoplasia, and mesothelioma
2. Diagnosis
 a. Thoracic radiography and ultrasonography may reveal a mass in addition to pleural fluids
 b. The fluid may be classified as modified transudate, nonseptic exudates, or chyle
3. Treatment involves drainage of the pleural effusion and treating the underlying neoplasia

Supplemental Reading

Berkwitt L, Prueter JC. Diagnostic methods in respiratory disease. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1622-1629.

Bjorling DE. Thoracic trauma. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1715-1723.

Bonagura JD, Sherding RG. Respiratory infections. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1684-1695.

Carothers MA, Alverez FJ. Respiratory neoplasia. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1708-1714.

Ettinger SJ, Kantrowitz B. Diseases of the trachea. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine, Diseases of the Dog and Cat*, 6th ed. St Louis, 2005, Saunders, pp. 1217-1232.

Fingland RB. Obstructive upper airway disorders. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1651-1664.

Johnson LR. Bronchopulmonary disease. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1665-1683.

Johnson LR. Diseases of the small airways. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1233-1238.

Mertens MM, Fossum TW, MacDonald KA. Pleural and extrapleural diseases. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1272-1283.

Nelson OL, Sellon RK. Pulmonary parenchymal disease. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine, Diseases of the Dog and Cat*, 6th ed. St Louis, 2005, Saunders, pp. 1239-1265.

Sherding RG, Birchard SJ. Pleural effusion. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1696-1707.

Venker-van Haagen AJ. Diseases of the nose and nasal sinuses. In Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine, Diseases of the Dog and Cat*, 6th ed. St Louis, 2005, Saunders, pp. 1186-1195.

26 CHAPTER

Restraint

Valerie A. Chadwick

INDICATIONS

I. Facilitate control for physical examination. Strive for minimum effective restraint
II. Prevent the animal from harming itself
 A. Prevent self-mutilation
 B. Avoid removing bandages
 C. Keep from jumping off examination table
III. To administer oral, injectable, or topical medications
IV. Perform certain procedures, such as applying bandages or catheterization
V. Protection of personnel. Veterinarian may be legally responsible if client is hurt by their own animal during a veterinary procedure
VI. Key to remember: "More is not better"

VERBAL RESTRAINT

Most dogs and cats respond favorably when spoken to:
I. Use calm, reassuring voice
II. Speak the animal's name
III. May try appearing less large and overbearing
 A. Hunker down
 B. Offer hand to sniff
 C. If you are accepted, animal's body will relax, may sniff hand, dog may wag tail and approach

PHYSICAL RESTRAINT OF DOGS

I. Lifting
 A. Small dogs: Grasp around thorax gently behind the elbows
 B. Medium dogs: Place one arm under the dog's neck with forearm holding dog's head securely, place other arm underneath or over the top of dog's abdomen or thorax, and pull dog close to chest of person restraining
 C. Large dog: May need two people; one person places arms around forequarters, and one person places arms around hindquarters; both people on the same side of the dog
 1. If the dog is male, it might object to being lifted under the flank area near the prepuce
 2. The person at the rear of the dog will need to have one arm forward of the prepuce when lifting
II. Standing restraint
 A. Forequarters and hindquarters need to be controlled to prevent the dog from jumping or falling if on an examination table
 B. Place one arm under dog's neck to hold dog's head securely
 C. Place other arm underneath or over the top of the dog's abdomen or thorax
 D. Pull the dog close to the chest of the person restraining
III. Sitting or sternal recumbency
 A. Place one arm under dog's neck to hold dog's head securely
 B. Place other arm around dog's hindquarters, and tuck in to the restrainer's inner elbow
 C. Pull the dog close to the chest of the person restraining
IV. Lateral recumbency: Small and medium dogs
 A. With the dog standing, reach over the top of the dog and grasp the foreleg (proximal to carpus) and rear leg (proximal to tarsus) of the dog closest to the restrainer
 B. Gradually lift the dog's body and slide slowly down and against the restrainer's body until in lateral position
 C. Restrainer uses the forearm nearest to the dog's head to exert pressure on the neck and side of head to keep immobilized
V. Muzzles and mouth gags
 A. Commercial muzzles
 1. Several sizes must be kept on hand
 2. Nylon, basket, or leather available
 B. Gauze muzzle (Figure 26-1)
 1. For most dogs, the strip of gauze needs to be 90 cm long
 2. Make a loop with one half of square knot with diameter of loop twice the diameter of the dog's nose
 3. Slip loop over dog's nose with ends above dog's head, and tighten by pulling on ends
 4. Cross loose ends under the dog's lower jaw
 5. Bring ends of gauze behind dog's ears and tie in bow
 6. The bow allows for quick release in case of difficulty breathing or vomiting
 7. Many dogs will try to push the loop off the nose with its forepaw, so be prepared to restrain the front legs from doing so immediately
VI. Mobility-limiting devices: Elizabethan collar
 A. Resembles wide, stiffly starched collars popular in seventeenth-century England



Figure 26-1 Hold the long ends pinned to your palms. Step up to the dog with the loop held open and start to slide it over the dog's muzzle. (From Sheldon CC, Topel J, Sonsthagen TF. *Animal Restraint for Veterinary Professionals*. St Louis, 2006, Mosby.)

B. Place a stiff material beyond the tip of the dog's nose to avoid chewing or licking its body, sutures, bandages, and so forth
C. Commercial plastic cone-shaped collars, or homemade from buckets, large bottles, or sheets of plastic
D. No sharp edges may be present
E. Secure collar to the dog's neck by gauze or to the dog's collar
F. Verify that the dog knows how to eat and drink with collar on

VII. Chemical restraint
A. Reason is to remove anxiety
B. Dogs may still bite when tranquilized or sedated
C. Risk is involved, and all animals must be closely monitored

PHYSICAL RESTRAINT OF CATS

I. Carrying
A. Move from place to place in towel or cat carrier
B. Physically carry a cat placed with hindquarters under the elbow area of restrainer and pressed firmly to holder's body; cat is in sternal position along forearm of holder with both front legs being held together with one hand; the other hand gently rests on back of the neck prepared to scruff if the cat struggles

II. Sternal recumbency
A. Place one forearm on each side of the cat's body with cat's head facing away from restrainer
B. Immobilize the head by placing both thumbs on top of the cat's head, and all fingers under the lower jaw

III. Lateral recumbency
A. Minimal restraint
1. While the cat is standing, restrainer reaches over the back of the cat, grasps both front legs with the forearm closest to the head and both back legs with the other forearm, and slides the back of cat against his or her body to lateral position
2. Holder may then use one hand to restrain all four legs and place the other hand around the cat's head with the jaws being held closed by the fingers and thumb
B. Moderate restraint (Figure 26-2)
1. Restrainer grasps as much loose skin as possible at the back of the neck and scruffs the cat with the hand closest to the cat's head
2. Using the other hand, the restrainer holds both rear legs proximal to the tarsus and stretches out the hind legs

IV. Muzzles
A. Commercial muzzles
1. Several sizes must be kept on hand but not as many as for dogs
2. Nylon and leather styles are available
B. Gauze muzzle
1. Create one half a square knot with a loop twice the diameter of the cat's nose
2. Place cat's nose inside the loop, tighten ends around the nose with the first knot underneath the jaw
3. Both ends pass behind the ears, tie with square knot
4. One free end of gauze is passed over forehead, under the loop on top of the nose, and tied back to other loose end, forming a knot on the top of the head

V. Mobility-limiting devices
A. Towel
1. Place bath towel on surface
2. Cat is placed across width of towel with head towards the edge of the towel
3. Begin with either side of towel, extend towel up toward ceiling, continuing over the dorsum of the cat, bringing the edge of the towel to be firmly wrapped across the neck of the cat



Figure 26-2 Gently stretch and rotate the cat over on its side onto the table. Lay the cat's back along your forearm. (From Sheldon CC, Topel J, Sonsthagen TF. *Animal Restraint for Veterinary Professionals*. St Louis, 2006, Mosby.)

4. Repeat using other side of towel crossing over the opposite direction
5. Creates a "kitty burrito" with only the head protruding

B. Cat bag
1. Several sizes must be kept on hand
2. Canvas or nylon with one or more zippers or strips of Velcro
3. With long zipper completely open, place cat inside cat bag facing the point at which the zipper would end closure
4. If available, fasten Velcro behind the neck of the cat
5. Quickly zip the bag closed, zipping toward the head of the cat
6. Allows access to multiple legs and feet as well as dorsum of cat

VI. Chemical restraint
A. Injectables may be administered for tranquilization or at an anesthetic dose
B. Cats may also be tanked down using a special chamber with gas anesthesia
C. Risk is involved and all animals must be closely monitored

Supplemental Reading

Crow SE, Walshaw SO. *Manual of Clinical Procedures in the Dog and Cat.* Philadelphia, 1987, Lippincott Williams & Wilkins, pp. 3-29.

McCurnin DM, Bassert JM. *Clinical Textbook for Veterinary Technicians*, 6th ed. Philadelphia, 2006, Saunders.

Sheldon CC, Topel J, Sonsthagen T. *Animal Restraint for Veterinary Professionals.* St Louis, 2006, Mosby.

27 CHAPTER

Soft Tissue Surgery

S. Brent Reimer

GENERAL INFORMATION

I. Wound classification
Wounds are classified based on the degree of contamination. As the degree of contamination increases, the postoperative infection rate can generally be expected to increase as well. The "critical" level of bacterial contamination that begets infection is classically greater than 10^5 organisms per gram of tissue, but variables other than population play a role (i.e., the virulence of the organism, blood supply of tissue involved, host defense mechanisms). Surgeries are classified as one of the following four types:
 A. Clean: A surgically created wound (nontraumatic) not involving the respiratory, gastrointestinal (GI), or genitourinary tract. No breaches in the tenets of aseptic technique
 B. Clean-contaminated: Controlled entrance into the respiratory, GI, or genitourinary tract, avoiding spillage of contents into the surgical field or with a minor breach in aseptic technique
 C. Contaminated: Surgical field subjected to gross spillage of infected tissues or contents of respiratory, GI, or genitourinary tract. Also seen with a major breach in aseptic technique and in "fresh" (less than 4 to 6 hours) traumatic wounds
 D. Dirty: Traumatic wound with devitalized tissues or delayed treatment (longer than 4 to 6 hours), transaction of "clean" tissues encountered during surgery to gain access to abscessed tissues

II. Antimicrobial prophylaxis
Antimicrobial prophylaxis is defined as the administration of an antimicrobial agent *before* the contamination event, typically the surgical incision. Therefore, these agents should be given preoperatively 30 and 60 minutes *before* creation of the incision. However, the continuation of antibiotic prophylaxis into the postoperative period is indicated in some very specific circumstances. Decisions regarding which antimicrobial to administer should be directed by anticipated pathogens present and their susceptibility profile. Currently, no evidence has been found that substantiates the routine continuation of antimicrobial administration postoperatively.

III. Patient preparation
 A. Hair removal: Clipping is preferred over shaving because it incurs less skin trauma. The clipping should be performed immediately before surgery and should take place in an area independent of the operating room
 B. Skin preparation: Antiseptic agents are used to reduce the bacterial colonization of the surgical field before surgery. The preferred agents are bactericidal. Commonly used agents include chlorhexidine or povidone-iodophor compounds intermittently rinsed with either sterile saline or isopropyl alcohol. Chlorhexidine may cause a decreased number of skin reactions compared with povidone-iodophor compounds. One report states that the use of chlorhexidine scrubs with isopropyl alcohol rinses is inferior to chlorhexidine scrubs with sterile saline rinses

SUTURE INFORMATION

I. Suture materials
 A. Suture is classified as absorbable or nonabsorbable. Most absorbable suture materials lose much of their tensile strength within 60 days of implantation. Most absorbable sutures undergo tissue hydrolysis, but some are absorbed via phagocytosis (e.g., chromic surgical gut)
 1. Nonabsorbable suture materials include silk, nylon, and polypropylene
 2. Absorbable suture materials include polydioxanone, polyglactin 910, chromic surgical gut, polyglycolic acid, poliglecaprone 25, and polyglyconate
 B. Suture is further classified as either monofilament or multifilament ("braided"). Multifilament suture materials inherently possess more capillarity, thus allow more bacteria to "wick" into areas in which they are used. Monofilaments possess less of this capillary action and thus are a better choice for contaminated wounds. Multifilament suture materials typically have less memory and often possess better handling characteristics compared with monofilament materials
 1. Monofilament sutures include polydioxanone, poliglecaprone 25, polypropylene, polyglyconate, and nylon
 2. Multifilament sutures include silk, polyglactin 910, polyglycolic acid, and chromic surgical gut
 C. Suture can further be classified as synthetic or natural (organic)
 1. Natural suture materials include surgical gut and silk

2. Synthetic suture materials include polyglactin 910, polyglycolic acid, polydioxanone, polypropylene, and polyglyconate

D. Suture selection should be individually tailored to the tissue and expected wound environment. In general, the suture should be as strong as, but should not greatly exceed, the tensile strength of the involved healing tissue. For wounds in which bacteria are anticipated to be present (GI surgery, contaminated wounds), typically a monofilament absorbable suture is recommended (e.g., polydioxanone)

E. Suture patterns include inverting, everting, and appositional patterns. Appositional and inverting patterns are most commonly used
 1. Inverting suture patterns include the Lembert, Halsted, Cushing, Connell, Parker-Kerr, and pursestring
 2. Appositional suture patterns include the simple interrupted, simple continuous, cruciate, and Gambee

BODY CAVITIES AND HERNIAS

I. Abdominal cavity
 A. Most commonly approached through a ventral midline incision through the linea alba via a midline celiotomy
 B. The holding layer of the abdomen is the external rectus fascia. It is imperative that this layer be included in abdominal closures to prevent dehiscence

II. Hernias
 A. Umbilical hernia
 1. Congenital defect believed to be heritable in some breeds
 2. Often asymptomatic but could have visceral entrapment
 3. Herniorrhaphy is the surgical closure of the hernia
 4. Prognosis is good and recurrences are uncommon
 B. Cranial pubic ligament hernia
 1. Traumatic avulsion of the cranial pubic ligament from the pubic bone
 2. Commonly allows caudal abdominal viscera to escape the abdominal cavity and reside in the subcutaneous tissues
 3. Diagnosis: Suspicion in a patient with abnormal swelling near pelvic inlet after a traumatic event. Bruising of the skin overlying the swelling is also a suspicious finding. Radiographs may reveal a loss of the "stripe" of the ventral abdominal wall on a lateral film as it courses toward its typical insertional point on the cranial edge of the pubis. Viscera may also be readily apparent on radiographs. Abdominal ultrasound may also be useful
 4. Treatment: Herniorrhaphy. The avulsed ligament often has to be secured to holes predrilled into the pubic bone to gain purchase.
 5. Prognosis is favorable for patients without significant concurrent injuries
 C. Inguinal hernia
 1. Traumatic: Can occur in any dog or cat
 2. Nontraumatic: Most typically associated with intact, middle-aged female dogs or young male dogs. Presumably associated with a delayed closure of the inguinal ring to allow the testicles to descend
 D. Scrotal hernia is most common in chondrodystrophic dogs
 E. Femoral hernia
 1. Male or female dogs are affected
 2. Can present with a nonpainful swelling over the mid-thigh or can have vomiting or pain with entrapment
 F. Perineal hernia
 1. More common in dogs than cats
 2. Much more common in intact males, link to androgens
 3. Failure of the muscles of the pelvic diaphragm allows abdominal organs to escape. Omentum most commonly entrapped and dogs present with tenesmus, dyschezia, diarrhea, and a fluctuant nonpainful swelling in the perineal region. Can be unilateral or bilateral. Can become an emergency if bladder becomes entrapped
 4. Diagnosis: Typically a clinical diagnosis; rectal examination is useful in the diagnosis of this disease
 5. Herniorrhaphy, most commonly using an internal obturator roll-up technique. Concurrent castration is also highly recommended.
 6. Prognosis: Generally fair to good, but recurrence is relatively common
 G. Diaphragmatic hernia
 1. Can be traumatic (acquired) or congenital
 2. The most common congenital diaphragmatic hernia is called a peritoneopericardial diaphragmatic hernia
 a. Can occur in cats and dogs
 b. Can be asymptomatic or cause problems related to the cardiovascular, respiratory, or GI tracts
 c. Direct communication between the abdomen and the pericardial sac
 d. May be accompanied by concurrent sternal defects or, in dogs, cranial abdominal wall hernias. Domestic long-haired cats and Weimaraner and cocker spaniel dogs appear to be predisposed
 e. Radiographic signs: Enlarged cardiac silhouette, tracheal elevation, loss of diaphragmatic border, gas-filled structures within the pericardial sac
 f. Treatment: Surgical herniorrhaphy if clinically affected. Surgical approach is via a ventral midline celiotomy, which can be extended into a caudal sternotomy if necessary
 g. Prognosis is favorable
 3. Traumatic diaphragmatic hernias are more common than congenital diaphragmatic hernias in small animals
 a. Motor vehicle accidents are the most common cause but can result from many events that cause intraabdominal pressure to elevate quickly. This causes the lungs to

deflate quickly, which creates a significant pressure differential between the abdominal and pleural compartments. This causes the diaphragm to be under significant stress, and ruptures can occur

b. Patients with diaphragmatic hernias are often in shock as a result of the traumatic event. Concurrent injuries are common and should be looked for; may present with dyspnea, tachypnea, cyanosis, or tachycardia
c. Physical examination may reveal dull heart and lung sounds, intrathoracic borborygmi as a result of GI organs being present in the thoracic cavity, minimal ability to generate meaningful chest excursions, significant abdominal component to respiration, and potentially an abdomen that appears "deflated," which is due to the abdominal contents now residing in the thoracic cavity
d. Initial patient stabilization is often necessary. This is accomplished by providing oxygen supplementation, potentially elevating the cranial end of the patient in an effort to encourage thoracic contents to "leak" back into the abdomen. Pleural effusion is commonly present and can be removed via thoracocentesis in an effort to improve breathing
e. Diagnosis is obtained via plain radiographs most commonly. A loss of the diaphragmatic line may be appreciated; a loss of the cardiac silhouette, displacement of the lungs by soft tissue or fluid opacity structure, or presence of gas-filled GI organs can also be seen on occasion. If a definitive diagnosis is not yet obtained, a water-soluble positive contrast agent can be injected into the peritoneal cavity in a procedure called a *positive contrast celiogram*. An abnormal communication between the abdominal and thoracic cavities would allow contrast agent to enter the thoracic cavity. An upper GI study using barium administered per os may also reveal loops of intestine within the thoracic cavity. Ultrasound may also be useful in obtaining the diagnosis if necessary
f. Treatment: Mechanical ventilation is necessary during this procedure. Patient should be stabilized before being taken to surgery to correct. Patients with gastric entrapment may be at an increased risk for acute respiratory decompensation resulting from progressive gastric distension. These patients should be monitored closely and potentially taken to surgery on an emergency basis. Surgical correction is achieved via ventral midline celiotomy. Rarely, this incision needs to be extended into a caudal sternotomy. The rent is identified, and gentle traction is placed on the herniated organs to place them back into the abdomen. The liver is the organ most commonly herniated through the diaphragm. Occasionally, the rent needs to be enlarged to allow the herniated organs to be replaced into the abdomen. The rent is then sutured, typically in a simple continuous pattern. A thoracostomy tube is placed to facilitate reestablishment of negative intrapleural pressure
g. Prognosis: Typically good in patients that can be stabilized. Recurrence is uncommon

SURGERY OF THE INTEGUMENT

I. Wounds
 A. Healing of the integument is influenced by the wound environment as well as host factors. The healing of wounds occurs in the following overlapping phases:
 1. Inflammatory phase. Occurs immediately after the wound has been created
 2. Debridement phase. Host cells remove damaged or necrotic tissue
 3. Repair phase. Generally begins several days after the injury
 B. Most surgical wounds are weakest during the "lag phase" of wound healing, which occurs 3 to 5 days after surgery. Most surgical dehiscences occur during this time
 C. Host factors that slow wound healing include excessive glucocorticoid levels (either endogenous or exogenous), diabetes mellitus, malnourishment, and hypoalbuminemia
 D. Wounds can heal via several different mechanisms:
 1. Primary closure. Surgical closure of viable tissue without delay
 2. Delayed primary closure. Typically contaminated wounds. Wound cleaned and lavaged for 2 to 5 days after surgery until contamination is under control, and then wound closure is performed
 3. Secondary closure. Wound maintained as an open wound and closed subsequent to granulation tissue formation (more than 5 days after creation of the wound)
 4. Second-intention healing. Wound allowed to heal via granulation, wound contraction, and epithelialization without surgical manipulation

II. Specific diseases of the integument
 A. Neoplasia
 1. Mast cell tumors: Most common cutaneous malignancy of dogs. All are considered malignant in dogs. Exist as grade 1, 2, or 3, with the higher the grade indicating a more anaplastic and biologically aggressive tumor. Typically occur in the skin but can also occur in the bone marrow or internal organs (liver, spleen, GI tract). In cats, cutaneous mast cell tumors are typically benign and have a predisposition for the head and neck. Visceral involvement in cats indicates malignancy
 a. Signalment: Predisposition in certain breeds (boxers, pugs, and Boston terriers). Generally middle-aged or older animals
 b. Diagnosis: Described as the "great imitator" because of its tendency to have no typical or highly predictable appearance. Should be

considered a differential diagnosis for any cutaneous or subcutaneous mass. Mass can increase and decrease in size as a result of degranulation of intracellular histamine granules. Typically exfoliates cells readily on fine-needle aspirate (FNA) to obtain diagnosis. Cytology reveals a round cell population with granules commonly seen. Grade can only be obtained via histopathological appearance via biopsy

c. Treatment: Wide surgical excision is the treatment of choice. Classically, 3-cm margins have been recommended. This recommendation was based primarily on empirical thought rather than scientific evidence. Recent reports may support less aggressive surgical margins as being as effective. Classically chemotherapeutic interventions centered on prednisone or vinblastine have been used. May also need a histamine 2 (H_2) blocker if the increased levels of H_2 in the blood are causing GI ulceration. May respond to radiation therapy

d. Prognosis: Good with successful removal of masses with clean margins. Guarded to poor with grade 3 tumors or tumors which have already metastasized (regional lymph nodes most commonly)

2. Mammary masses: Uncommon in male dogs and male cats but can occur. Most common tumor in female dogs. Cause is unknown but linked to hormonal influences, so decreased incidence in dogs spayed early in life. Approximately 50% are malignant in dogs, between 80 and 90% are malignant in cats

a. Signalment: Typically intact females or females spayed late in life

b. Diagnosis: Often a palpable mass in the mammary chain. Normal dogs have five mammary glands on each side; cats normally have four glands on each side. FNA may be diagnostic

c. Treatment: Surgical excision of the disease. In dogs, typically a lumpectomy or mammectomy is performed for smaller masses. In cats, more aggressive surgery is indicated and typically takes the form of bilateral radical mastectomy

d. Prognosis: Depends on histologic type, stage of disease, and ability to resect diseased tissue

SURGICAL DISEASES OF THE GI TRACT

I. Oral cavity

A. The oral cavity is inherently contaminated with bacteria but also has a robust blood supply. Consequently, healing typically occurs despite the contaminated environment

B. Surgery within the oral cavity has an increased risk of wound dehiscence as a result of the inherent contamination, increased tension often encountered, as well as the constant use of the oral cavity for daily activities (e.g., eating, swallowing saliva)

C. Neoplasia of the oral cavity

1. Malignant melanoma: Most common oral tumor of dogs. Aggressive locally and is often metastatic. Treatment centers on removing the local disease and on appropriate staging. Long-term prognosis is poor
2. Squamous cell carcinoma: Most common oral tumor of cats; occur with frequency in dogs. Locally invasive and can metastasize. Treatment centered on removal of the local disease and staging. Can be tonsillar in dogs. Prognosis is guarded in dogs and grave in cats
3. Fibrosarcoma: Locally aggressive but late to metastasize. Treatment primarily involves wide excision of the primary tumor
4. Osteosarcoma: Locally aggressive and high metastatic potential. Prognosis in dogs is poor but typically better than appendicular osteosarcoma
5. Epulides: Most common class of benign oral tumors. Three types: Acanthomatous (most common), fibromatous, and ossifying exist. Arise from the periodontal ligament. Treat with excision or radiation therapy
6. Ameloblastoma: Benign; arise from dental lamina. Young dogs
7. Oral papillomatosis: Benign process, typically younger dogs. Viral cause. Usually multiple gray masses on gingival or buccal mucosa. Typically requires no surgical intervention and spontaneously regresses

D. Cleft palate: Brachycephalic dogs and Siamese cats are predisposed. Often diagnosed at birth but may manifest because of difficulty nursing, milk coming from nostril during nursing, pneumonia (aspiration), small stature, or a failure to thrive

1. Primary cleft: Lip and premaxilla (harelip)
2. Secondary cleft: Cleft in the hard and soft palate
3. Treatment: Surgical correction of the defect using local tissue flaps most commonly. Prognosis is fair, but multiple surgeries should be anticipated to revise defect

E. Salivary mucocele: Also called a sialocele, or salivary cyst. Dogs have four paired sets of salivary glands, including the zygomatic, parotid, mandibular, and sublingual. The mandibular salivary gland duct courses from the gland rostrally and is continuous with the sublingual chain. These glands eventually empty at the rostral aspect of the lingual frenulum. These are the glands most commonly affected by a salivary mucocele. Four individual presentations can occur:

1. Nonpainful ventral cervical swelling
2. Pharyngeal swelling, which can lead to profound dyspnea
3. Rannula, submucosal swelling under the tongue
4. Exophthalmia, which is due to retrobulbar leakage of the zygomatic gland

5. Diagnosis typically derives from clinical presentation and findings. Aspiration of the swelling (if performed) yields viscous fluid rich in protein with neutrophils associated with the inflammation. Can also perform contrast sialogram if needed to confirm diagnosis or determine which side is affected
6. Treatment: Excise the affected gland(s). Prognosis is excellent with surgery. Repeated drainage of the mucocele is very rarely effective in resolving the disease

F. Salivary gland neoplasia: Rare disease. Typically malignancy. Treatment via surgical excision

II. Esophagus

A. Animals afflicted with esophageal disease can exhibit ptyalism, regurgitation, coughing (particularly with secondary aspiration pneumonia), dysphagia, weight loss, or may be recumbent if severely debilitated

B. The esophagus does not heal as readily as many of the other areas of the GI tract because of its decreased vascularity that results from its segmental blood supply as well as the fact that the esophagus lacks a serosal layer, is in constant motion with day-to-day activities such as breathing and swallowing, and does not typically have access to the omentum to accentuate the healing process

C. Esophageal foreign bodies: Typically younger animals. Bones, rawhides, toys, fishhooks. Most commonly lodge at the thoracic inlet, base of the heart, or near the diaphragm
1. Diagnosis: Radiographs, contrast studies, esophagoscopy
2. Treatment: Preferable to remove the foreign body endoscopically; if that is not possible, then removal by surgical intervention
3. Prognosis: Good if esophagus is healthy; if damaged, esophageal stricture can result

D. Esophageal strictures: Can be intraluminal or extraluminal compressions. Can be the result of many insults, including previous esophageal surgery, esophagitis, or neoplasia. Has also been linked to administration of certain medications (e.g., doxycycline capsules in cats) because of the caustic medications maintaining mucosal contact for an extended period
1. Diagnosis: Radiographs, contrast studies, esophagoscopy
2. Treatment: Esophageal resection and anastomosis, bougienage
3. Prognosis: Guarded because recurrence is common

E. Esophageal neoplasia: Rare in cats and dogs. Typically progressed at time of diagnosis. Has been linked with *Spirocerca lupi* infestation

F. Vascular ring anomalies: Result from persistence of embryologic structures that normally regress in utero. Patients affected most commonly present for regurgitation, which typically begins shortly after weaning to solid foods, which cannot pass the constriction. Irish setters and German shepherd dogs are breeds that are predisposed. Multiple littermates may be affected. May remain of small stature and grow more slowly than unaffected littermates. Ventral cervical swelling can be observed near the thoracic inlet corresponding to dilated esophagus. May be coughing if have concurrent aspiration pneumonia. There are several different vascular ring anomalies, but the persistent right aortic arch is the most common and accounts for more than 90% of the vascular ring anomalies
1. Diagnosis: Radiographs typically show a dilation of the esophagus cranial to the base of the heart. Also want to rule out concurrent aspiration pneumonia. Contrast studies may also be useful. Echocardiography may be useful in determining the abnormal vessel(s) involved
2. Treatment: Surgical transection of the constricting vessel. For a persistent right aortic arch, this is accomplished through a left lateral thoracotomy performed at the fourth intercostal space
3. Prognosis: Typically good; esophageal motility problems can persist

G. Cricopharyngeal achalasia: Disorder of swallowing where food bolus that has formed in the mouth is not allowed to enter the esophagus because of failure of the cricopharyngeal muscle to relax during swallowing. Springer and cocker spaniels are predisposed. Typically diagnosed at weaning
1. Diagnosis: Clinical signs, dynamic contrast studies of the patient swallowing
2. Treatment: Cricopharyngeal myectomy
3. Prognosis: Guarded to fair

H. Hiatal hernia: Protrusion of the abdominal portion of the esophagus as well as potentially portions of the stomach through the esophageal hiatus in the diaphragm into the caudal portion of the thorax. Shar-peis and brachycephalic breeds are predisposed
1. Diagnosis: Radiographs, but the condition can be dynamic and so can have normal radiographs and a hiatal hernia still be present
2. Treatment: Medical management with H_2 blockers, gastroprotectants. If no positive response to medical management, surgical correction via gastropexy and hiatal reduction is needed
3. Prognosis: Typically good.

III. Stomach

A. Gastric dilatation-volvulus (GDV) syndrome: An extremely serious medical condition that results from the stomach rotating to varying degrees on its own axis. Gas subsequently becomes trapped within the gastric lumen and cannot escape. The stomach dilates, which subsequently compresses the systemic and portal venous systems within the abdomen. This significantly decreases cardiac return, and the patients become cardiovascularly unstable because of their functional hypovolemia. *This condition represents a surgical emergency!* (Figure 27-1)
1. Signalment: Typically middle-aged large- or giant-breed dogs. Dogs with a deep-chested

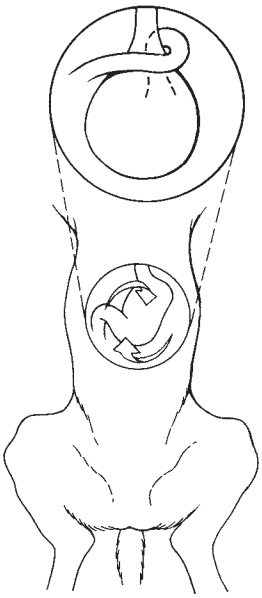


Figure 27-1 Direction of gastric rotation in most dogs with gastric dilatation volvulus (GDV). (From Fossum TW et al. *Small Animal Surgery*, 3rd ed. St Louis, 2007, Mosby.)

conformation are predisposed. Having a first-degree relative with a history of GDV is a risk factor for this disease; however, can occur in any dog

2. History: Typically, acute onset of vomiting, which can be either productive or non productive, lethargy, abdominal pain, apprehension, ptyalism. May coincide with recent exercise after a meal but not consistently
3. Diagnosis: Clinical picture of acute onset of cardiovascular compromise in a previously healthy dog of classic conformation is supportive of the diagnosis. May have distended abdomen, but possibly not, because the dilated stomach may lie completely recessed under the ribs and not be palpable. Radiographs are useful for diagnosis, with the right lateral radiograph typically showing the classic signs of gastric compartmentalization ("double bubble") and gastric malposition
4. Treatment: Stabilization is of paramount importance. Several large-bore intravenous (IV) catheters should be placed in the patient. The catheters should not be placed in the hindlimbs, as blood from the caudal portions of the body is not typically reaching the heart effectively. Often in obstructive shock and should have intravascular resuscitation performed immediately with either crystalloids or colloids or a combination. Can also have respiratory compromise because of a large stomach decreasing thoracic expansion for respiration and may benefit from oxygen supplementation. Gastric decompression should also be attempted. A large-diameter orogastric tube should be passed into the stomach to allow the entrapped gas to escape. If this is not successful, percutaneous gastrocentesis can be performed using a large hypodermic needle or a large IV catheter. After the gas has escaped the stomach using this technique, reattempting to pass the orogastric tube may be successful because the gastric pressure is typically reduced. Temporary gastrostomy has also been successful in patient stabilization in rare instances when previous attempts to decompress the stomach have been unsuccessful. Once the patient is stable, surgical intervention should be performed immediately on obtaining a definitive diagnosis. Stabilization takes precedence over diagnostic testing
5. Surgery
 a. Reposition stomach
 b. Assess tissue viability and resect any necrotic or questionable tissue
 (1) Color: Pink and red are acceptable; dark tissue is not. This can occasionally be misleading if the serosal surface appears normal, but the intraluminal surface may be necrotic
 (2) Pulses
 (3) Palpation: Viable tissue should not be overly thin and friable
 (4) Bleeds on cut surface: Can be misleading, and correct interpretation is critical
 c. Prevent recurrence via gastropexy. Many different techniques exist, and the choice is based largely on surgeon preference. The gastropexy should create a permanent adhesion between the patient's abdominal body wall and pyloric antrum. This means that the gastropexy should be performed on the patient's right side. Described techniques include incisional, belt-loop, circumcostal, gastrocolopexy, and tube gastrostomy
6. Postoperative care: Cardiac rhythm abnormalities are common in patients with this disease. The most common arrhythmia is the occurrence of premature ventricular contractions, which can occur preoperatively, intraoperatively, or postoperatively. Interventional cues and treatments are covered elsewhere
7. Prognosis: Good with early identification and aggressive therapy. Negative prognostic factors include the presence of gastric necrosis and a blood lactate greater than 6 mmol/L at admission. Recurrence is exceedingly rare with an appropriate gastropexy

B. Gastric foreign bodies
 1. Presentation: Many will present with vomiting, anorexia, diarrhea, and a painful abdomen. Severity of clinical signs will vary considerably depending on degree of obstruction, time obstruction has been present, degree of dehydration, and other factors
 2. Diagnosis: History of a missing toy or household item; vomiting may be severe. Radiographs may reveal an obvious foreign body. Positive contrast agents can be administered to further assist with the diagnosis. If the

foreign body is obstructing the gastric outflow tract and the animal is losing gastric secretions in the vomitus, the patient may have an hypochloremic, hypokalemic metabolic alkalosis

3. Treatment: Smaller gastric foreign bodies may pass through the GI tract without assistance. If this technique is selected, patients must be monitored closely for signs of declining condition, in which case surgical intervention would have to be performed. Some will attempt to induce vomiting in an effort to have the patient expel the foreign body themselves, but the success rate is unknown and thought by many to be low. The vomiting may also exacerbate underlying esophagitis and can lead to aspiration pneumonia. Definitive therapy involves removal of the foreign body via gastroscopy or exploratory laparotomy and gastrotomy. Rarely is the stomach damaged to the point where a partial gastrectomy is necessary. Always perform an entire abdominal exploratory surgery to ensure that other foreign bodies are not present at other levels within the GI tract. The holding layer throughout the GI tract is the submucosa and must be incorporated into the gastrotomy closure. Gastrotomy closure can be performed numerous ways, including a one-, two-, or three-layer closure. Appositional or inverting suture patterns are typically used. Monofilament absorbable suture material is recommended

C. Gastric masses
 1. Benign masses may occur in the stomach. Leiomyomas arise from the smooth muscle of the stomach. Chronic hypertrophic pyloric gastropathy occurs most commonly in small-breed dogs and is typically acquired later in life. The cause is unknown. Treatment of these conditions can be instituted by marginal resection of the tissue involved. Prognosis is favorable.
 2. Most gastric neoplasms are malignant in dogs and cats. Adenocarcinoma is the most common gastric neoplasm in dogs, whereas lymphoma is the most common neoplasm in cats
 a. Presentation: Typically older animals. Clinical signs are often nonspecific and center around vomiting, anorexia and weight loss
 b. Diagnosis: Radiographs rarely will reveal a mass. Contrast radiographs and abdominal ultrasound may be useful in the diagnosis of this disease
 c. Treatment: Wide surgical resection of the diseased tissue. Typically disease is advanced at diagnosis, so biopsies of the liver and regional lymph nodes are also recommended. The mass may involve the pylorus, the biliary system, or both. A rerouting of the GI system or biliary tree may be necessary
 d. Prognosis: Typically poor

IV. Small intestine
 A. Intestinal foreign bodies
 1. Relatively common medical condition of dogs and cats. Typically result from dietary indiscretion. Can be the result of a simple item (e.g., toy, bone, stone) or from the patient ingesting a string (e.g., thread, dental floss, rope), in which case it is called a *linear foreign body*. In the case of a linear foreign body, the string gets lodged in one area of the GI tract, but peristalsis continues unabated. This causes the intestinal tract to slide up the string and accordionate. Classically, linear foreign bodies are associated with cats; thus a part of the physical examination of any vomiting cat includes close examination under the tongue to look for string caught under the tongue
 a. Presentation: Most commonly younger animals suffer from dietary indiscretion, but any animal may have an intestinal foreign body. Most commonly, the patients have vomiting, diarrhea, anorexia, and lethargy. If the intestine has perforated, the animal may show varying degrees of shock and could have a palpable fluid wave. This would be the result of septic peritonitis. These patients should have immediate stabilization and subsequent exploratory surgery as soon as they are stable enough to endure general anesthesia
 b. Diagnosis: Abdominal palpation may reveal a palpable foreign body. Abdominal radiographs may show an obstructive pattern in the small bowel or enteroplication in the case of a linear foreign body. Contrast studies can aid in the diagnosis if necessary, as can abdominal ultrasound
 c. Treatment: As with gastric foreign bodies, medical management can be attempted on rare occasions, but typically these patients will require surgical intervention. Full abdominal exploratory should be performed and the foreign body isolated. Viability of the bowel should be assessed. If the bowel is viable, then a simple enterotomy can be performed. The enterotomy is typically best performed immediately aborad to the obstruction in an effort to perform the surgery on only healthy bowel that has not experienced any degree of vascular compromise. If the bowel has questionable viability, a resection and anastomosis should be performed. An end-to-end anastomosis of the remaining ends of small intestine should be performed and is preferable to an end-to-side or side-to-side variety. Suture material should be a monofilament, absorbable variety of appropriate size. Healing of surgical sites can be enhanced by an omentopexy or performing a serosal patch to the area
 d. Prognosis: Typically, the prognosis is good. Low serum protein levels and the presence

of preoperative septic peritonitis may predict patients that may be at a higher risk for intestinal dehiscence and subsequent septic peritonitis

B. Septic peritonitis
 1. Diagnosis: Documentation of bacteria living in the peritoneal cavity. Most commonly diagnosed with cytology confirming the presence of intracellular or extracellular bacteria or both or food or plant material on abdominocentesis. A diagnostic peritoneal lavage may assist with the diagnosis in cases where patients lack a plethora of free abdominal fluid. Comparisons of glucose and lactate levels in the abdominal fluid with concurrent blood values may also assist with the diagnosis. May have a left shift on leukogram and could potentially be hypoglycemic
 2. Causes: Most commonly due to a ruptured viscous. GI rupture is the most common cause in dogs and cats. Other causes would be rupture of an infected level of the biliary system, rupture of an area of the urogenital tract, penetrating wound seeding the abdomen, iatrogenic in a postoperative patient
 3. Treatment: Medical stabilization such as IV fluid support, antibiotics based on bacterial identification or empirical selection based on suspected pathogen, identification of the cause of the septic peritonitis, surgical exploration of the abdominal cavity, and repair or removal of damaged organs
 4. Prognosis: Typically guarded to fair. Highly dependent on patient stability, promptness to identification, and subsequent surgical intervention

C. Intussusception
 1. Occurs when one segment of bowel telescopes into an adjacent segment. The inner segment is typically the portion on the orad side of the lesion and is called the intussusceptum; the outer segment is typically the more aborad segment and is called the intussuscipiens (Figure 27-2)
 2. Signalment: Typically younger animals, although older animals can be affected. There is an underlying cause in almost all patients, and it is crucial to identify and treat it. In younger animals, intestinal parasitism is the most common cause, whereas in older animals it is often neoplasia. Other potential causes include enteritis (viral, bacterial), recent surgery, or trauma. German shepherd dogs may be predisposed
 3. History: Vomiting, diarrhea, may have blood in stool. Abdominal pain. May have an acute or chronic history as some intussusceptions may be present for a considerable time before they are diagnosed
 4. Diagnosis: May have a palpable mass in the abdomen. Radiographs typically reveal an obstructive intestinal pattern and potentially may reveal a soft tissue mass corresponding to the intussusception. Abdominal ultrasound is useful in the diagnosis of an intussusception. Occasionally, the intussusceptum migrates completely through the colon and can be seen protruding from the anus. These must be differentiated from a rectal prolapse via probing between the protruding organ and the anus itself. If it is a rectal prolapse, the probe will not be able to be passed into the anus, whereas if it is an intussusception the probe will pass easily between the intussusceptum and the anus

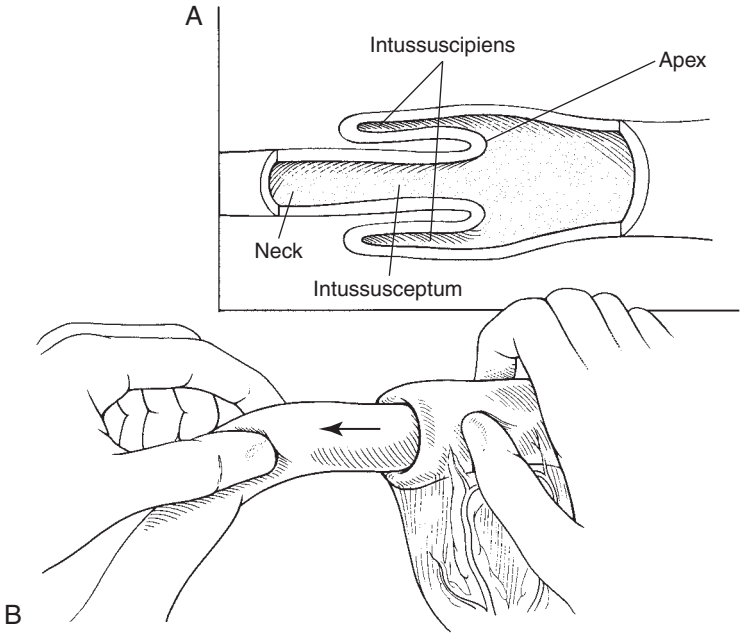


Figure 27-2 **A,** Configuration of an intussusception: Neck, intussusceptum, apex, intussuscipiens. **B,** To reduce an intussusception, place traction on the neck as you milk the apex out of the intussuscipiens. (From Fossum TW et al. *Small Animal Surgery*, 3rd ed. St Louis, 2007, Mosby.)

5. Treatment: Surgical exploration and attempted manual reduction of the intussusception (Figure 27-2). If the intussusception cannot be reduced or the bowel has questionable viability, then an intestinal resection and anastomosis is performed. Enteroplication is the process of suturing adjacent loops of bowel to each other through intermittently placed partial-thickness sutures. This is thought by some to decrease the incidence of the patient sustaining another intussusception. Must identify and treat underlying condition
6. Prognosis: Generally good if patient is stable

D. Intestinal neoplasia
1. Most intestinal masses are malignant, with adenocarcinoma and lymphoma being the most common types
2. Treatment: Resection and anastomosis most commonly
3. Prognosis: Typically guarded to poor

E. Intestinal volvulus
1. Condition when mesenteric attachment of the intestine twists around on itself and restricts venous drainage most commonly. Eventually leads to necrosis of the affected bowel. Can affect the entire bowel served by the cranial mesenteric artery (descending duodenum, jejunum, ileum, ascending and transverse colon) or smaller portions of the bowel (Figure 27-3)
2. Typically painful and may be in shock. German shepherds overrepresented
3. Treatment: Immediate surgical exploration
4. Prognosis: Guarded

V. Colon, rectum, and perineum

A. Because of the higher rate of complications associated with colonic surgery, attempts are typically made to minimize colonic surgical interventions. The higher rate of complications is directly related to the much higher concentration of bacteria in the colon compared with other levels of the GI tract. As such, when a foreign body is palpated in the colon during an exploratory surgery, it is recommended that the item be "milked" down to the level of the anus and manually extracted instead of performing a colotomy to remove it

B. Rectal prolapse: Protrusion of the distal colon and rectum from the anus. Varying degrees of involvement can be present in a patient. Typically, there is an underlying cause such as parasitic infestation or neoplasia. Treatment first attempts to replace the prolapsed tissue into the rectum and placing a loose pursestring suture for between 3 and 5 days to maintain the tissue within the rectum
1. Occasionally, necrotic tissue may need to be resected
2. Recurrent episodes can be treatment by a colopexy where the colon is permanently fixed to the body wall by placing sutures between the descending colon and the left body wall

C. Colonic masses: Benign adenomatous polyps and adenocarcinomas are the most common masses
1. Most are present after an owner notices blood in the stool or straining
2. Treatment is centered on surgical resection. Aggressiveness of the surgery is determined by the tissue type of the mass being treated and can vary from simple mucosal resection to colonic resection and anastomosis

D. Megacolon: More common in cats than in dogs. Causes include idiopathic (most common cause), pelvic narrowing often due to malunions of pelvic fractures, neurologic abnormalities, or endocrine disorders. Cats can present with constipation (difficult or infrequent passage of abnormally dry feces) or obstipation (passage of no feces). They may also have anorexia, vomiting, and even diarrhea if liquid feces can pass around the massive firm intraluminal concretions
1. Signalment: Typically acquired in middle-age or older. Occurs more often in cats than in dogs
2. History: Generally progressive constipation eventually leading to obstipation
3. Diagnosis: Often diagnosis can be obtained via history and physical examination findings of a large colon distended by very firm feces. Support for the diagnosis can be garnered by abdominal radiographs
4. Treatment
 a. Medical intervention: Typically performed before surgical intervention is attempted. Patients often have to undergo general anesthesia and manual evacuation at initial diagnosis to empty colon. Enemas assist in the initial deobstipation as well as in maintenance of patients long term. Increasing fiber content of the diet via either a specially formulated diet high in fiber or by adding fiber to the diet is also attempted. Stool softeners, laxatives, and prokinetic drugs (e.g., cisapride) can also be administered
 b. Surgical intervention: Typically performed in animals who do not respond to medical intervention, animals that become refractory to medical intervention, or in animals with owners unwilling to perform the medical interventions necessary. Surgical correction consists of a subtotal colectomy in which the vast majority of the patient's colon is removed via resection and either the ileum or very orad portion of the colon is brought into apposition with the very aborad portion of the colon remaining near the pelvic inlet. Cats are expected to have varying degrees of diarrhea postoperatively, which typically resolves between 1 and 2 months. Prognosis with surgical intervention is good

E. Anal sacculitis
1. Fairly common disease of dogs and can occur in cats
2. Clinical signs: Licking, tenesmus, irritation, scooting
3. Diagnosis: Rectal examination may reveal impacted and thickened anal sacs

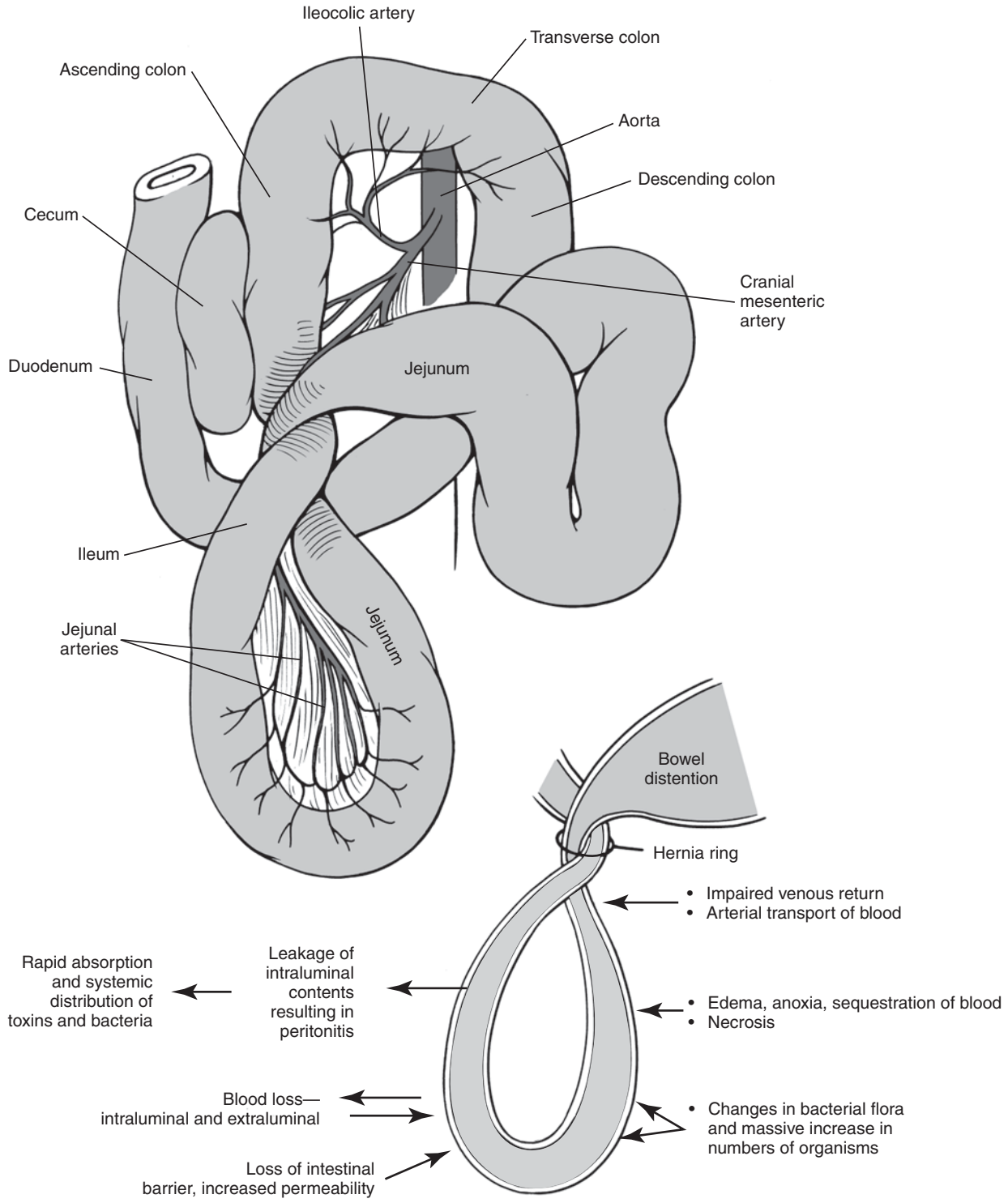


Figure 27-3 Pathophysiologic events associated with strangulating intestinal obstructions. (From Fossum TW et al. *Small Animal Surgery*, 3rd ed. St Louis, 2007, Mosby.)

4. Treatment: Manual evacuation of anal sac contents on a regular basis to prevent impaction. Some evidence of an immune-based component, so some will provide a hypoallergenic diet. If problems persist, then surgical intervention can be performed via open or closed anal sacculectomy

F. Anal sac masses
 1. By far the most common is the anal sac adenocarcinoma
 2. Signs: Can present after owner notices a swelling in the perineal region; can be polyuria or polydipsia (hypercalcemia is seen as a common paraneoplastic syndrome with this

disease), tenesmus, lethargy, passage of compressed feces. Females may be predisposed
3. Diagnosis: Rectal examination, FNA of mass can be performed. Metastasis is common with this tumor, particularly to the regional (medial iliac) lymph nodes so staging via abdominal ultrasound is recommended
4. Treatment: Surgical removal of the mass, with or without removal of the medial iliac lymph nodes
5. Prognosis: Guarded to poor, median survival time between 6 and 12 months

G. Perianal masses
1. Perianal adenoma
 a. Most are hormonally responsive and seen almost exclusively in intact male dogs
 b. Diagnosis: FNA of the mass reveals cells that have the appearance of liver cells, so it is also known as a *hepatoid adenoma*
 c. Treatment: Resection of the masses and castration
 d. Prognosis: Excellent
2. Perianal adenocarcinoma
 a. Often large, aggressive, and anaplastic
 b. Not linked to hormonal influence
 c. Treatment: Resection
 d. Prognosis: Guarded

VI. Liver
A. Portosystemic shunts
1. Can be congenital (more common) or acquired. Congenital shunts are most commonly single vessels; acquired shunts are most commonly multiple
2. Can be extrahepatic (more common) or intrahepatic (Figure 27-4)
 a. Classically, small-breed dogs have been associated with extrahepatic, and large-breed dogs have been associated with intrahepatic shunts. Yorkshire terriers, pugs, poodles, Labrador retrievers, and Irish wolfhounds are predisposed
 b. Cats can also have portosystemic shunts. Their signs are most commonly associated with the neurologic system (blindness, ptyalism, seizures) and has been purported to be linked with copper-colored irises. A cause for this link is unknown
3. Most commonly have signs associated with one or more of three body systems:
 a. GI: Vomiting, diarrhea, anorexia, failure to thrive
 b. Urinary: Associated with ammonium biurate crystals and urate stones
 c. Neurologic: Seizures, depression (particularly after high-protein meals), stuporous behavior. Can sustain a prolonged recovery after general anesthetic events
4. Signalment and physical examination findings: Typically small stature, may have been the "runt"; failure to grow normally, may have retained canine teeth, and cryptorchidism. Physical examination generally yields small stature, poor body condition, and small liver
5. Laboratory findings
 a. Complete blood cell count (CBC): Microcytic anemia, may have white cell alterations
 b. Serum chemistry: Low albumin, low blood urea nitrogen, low cholesterol, low glucose, low globulins. With congenital shunts, liver enzymes are typically normal or mildly increased, with acquired shunts liver enzymes are typically elevated as underlying liver disease is the cause of these shunts
 c. Urinalysis: Typically low specific gravity to urine owing to decreased amount of urea available to provide renal medulla with osmotically active substrate for countercurrent mechanism in the loop of Henle. May have ammonium biurate crystals
6. Other diagnostics
 a. Abdominal radiographs: Small liver, potentially enlarged kidneys
 b. Abdominal ultrasound: Operator dependent but may reveal presence, location, and morphology of the shunt
 c. Serum bile acids: Typically fasting sample within reference range or slightly increased; postprandial sample usually tremendously elevated
 d. Nuclear scintigraphy: Will provide information regarding the presence or absence of a shunt, but information regarding location and morphology of the shunt is minimal

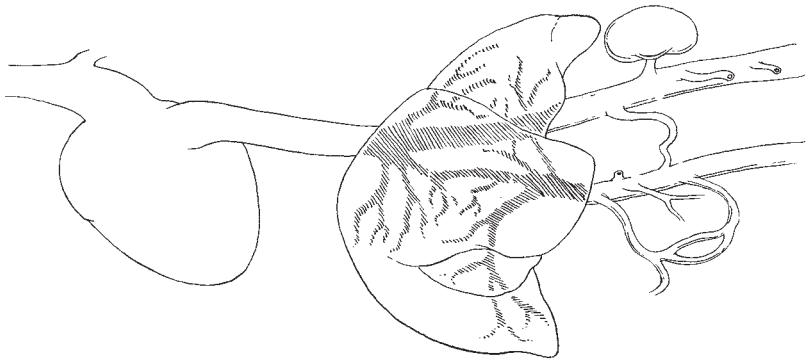


Figure 27-4 Schematic representation of an extrahepatic portacaval shunt and an intrahepatic portacaval shunt. (From Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Clinical Practice,* 3rd ed. St Louis, 2006, Saunders.)

e. Contrast portography: Radiopaque material is injected into the portal system and either traced into the liver in a normal animal, or it will outline the abnormal communication between the portal and systemic circulations. Typically requires general anesthesia, minor surgical procedure to catheterize a jejunal or splenic vein, and then injection of the material. Provides confirmation of the presence or absence of a shunt as well as useful morphologic information

7. Treatment
 a. Medical management: Associated with a poorer survival time than surgical intervention but can be used in patients to stabilize before surgery or for owners that decline surgery
 (1) Low-protein diet
 (2) Antibiotics to control colonic flora (metronidazole, neomycin, potentiated penicillins)
 (3) Lactulose to decrease intestinal transit time to decrease the time available to generate toxic byproducts of protein digestion as well as to trap ions blocking transport across the intestinal wall via acidification of the colonic contents
 (4) Anticonvulsants if necessary to prevent seizures
 b. Surgical intervention: Identify the shunt, then address vessel
 (1) Simple suture ligation: Can cause portal hypertension if the portal system cannot compensate for increased circulation immediately. Can measure portal pressures to predict
 (2) Ameroid constrictor: Inner casein (milk protein) ring and outer stainless steel ring. Outer ring restricts outward expansion of the protein as it imbibes fluid within the peritoneal cavity, forcing all expansion to occur inward
 (3) Bands made of cellophane, which causes inflammation within vessel and subsequent thrombosis
 (4) Obtain a liver biopsy to rule out underlying primary liver disease
8. Postoperatively animals should be closely monitored for the following:
 a. Hypoglycemia
 b. Portal hypertension
 c. Disseminated intravascular coagulation
 d. Seizures
 e. Hemorrhage
9. Prognosis: Better with surgery over medical management. Good prognosis with congenital extrahepatic. Fair with congenital intrahepatic as higher perioperative mortality rate. Guarded with acquired shunts, as typically significant liver disease is the underlying cause

B. Liver masses
 1. Metastatic disease is more common in dog and cat livers than is primary liver neoplasia
 2. Regenerative nodules are a normal and common finding in older patients. Avoid being overly pessimistic regarding finding liver nodules until histopathology confirms diagnosis
 3. Hepatocellular carcinoma: Most common primary liver tumor of dogs
 4. Cholangiocellular adenoma: Most common primary liver tumor of cats
 5. Treatment: Liver lobectomy
 6. Prognosis: Dependent on underlying disease

C. Liver-lobe torsion: Rare disease, most common in left lateral lobe; lobectomy is treatment of choice

D. Liver abscess: Rare disease, serious medical condition, treatment via lobectomy

VII. Pancreas

A. Pancreatitis is a potential sequela to pancreatic manipulations during surgery. Typically the inflammation is mild and self-limiting, but clinically significant inflammation can occur with robust handling of the pancreas

B. Insulinoma: β-cell tumor, insulin-secreting tumor
 1. Signalment: Typically larger-breed dogs (golden retriever, Labrador retriever), middle-aged or older
 2. History: Episodes of weakness, collapse, or seizures, which may or may not be associated with exercise or meals
 3. Physical examination is typically unremarkable but occasionally may find a poor body condition or signs of neuroglycopenia ramifications
 4. Diagnostics: Hypoglycemia in the face of concurrent normal or often increased insulin levels. Can use abdominal ultrasound to attempt to locate mass within pancreas
 5. Treatment
 a. Medical management
 (1) Prednisone
 (2) Small, frequent meals
 (3) Limit exercise
 (4) Diazoxide
 (5) Streptozocin
 b. Surgical intervention
 (1) Exploratory surgery with partial pancreatectomy is preferred
 (2) Biopsy regional lymph nodes and liver to stage disease
 6. Prognosis: In dogs, almost all are malignancies so long-term prognosis is guarded to poor. Improved survival times are seen with surgery compared with medical management

SURGICAL DISEASES OF THE URINARY TRACT

I. Kidneys: Nephrectomy

A. Performed for severe trauma to the kidney, catastrophic infection of the kidney, renal neoplasia

B. Unilateral nephrectomy causes no untoward effects on the patient long-term assuming a normally functioning kidney remains in the patient postnephrectomy

II. Ectopic ureters

A. Diagnosed in females more commonly than in males

B. Diagnosed in dogs more commonly than cats. Labradors, soft-coated wheaten terriers and Siberian huskies are overrepresented

C. Signs: Typically urinary incontinence since birth. Must be differentiated from behavioral problems. Most commonly unilaterally affected; consequently, many affected dogs can store and void urine normally as well
D. Can be intramural or extramural
E. Diagnosis: Ultrasound may reveal a dilated renal pelvis and hydroureter, which are commonly seen concurrently with this disease. Excretory urography is useful in identifying the disease and the location of the ectopia
F. Treatment: Surgical disease, typically in attempt to create new opening of the ureter into the urinary bladder and resect any abnormal tissue. Ureteronephrectomy should be reserved for only cases in which renal function of that collecting unit cannot be saved
G. Prognosis: Guarded; a substantial proportion of treated dogs will have some persistence of urinary incontinence. This is ascribed to an underlying problem with the urethral sphincter mechanism and is called *urethral sphincter mechanism incontinence*

III. Uroliths: The vast majority of urinary calculi occur in the lower urinary tract in dogs and cats
A. Struvite (triple phosphate)
1. Radiopaque stone
2. Most common stone in dogs; formerly was the most common stone in cats but has been surpassed by calcium oxylate more recently
3. Can be associated with urease-producing bacteria, so always rule out concurrent urinary tract infection
4. Can dissolve with special diet to lower urinary pH and antibiotics (if appropriate) but takes considerable time
5. Surgical removal of the uroliths is also an appropriate treatment, particularly in patients with clinical signs associated with the uroliths.

B. Calcium oxalate
1. Radiopaque stone
2. Recently identified as most common stone of urinary tract in cats
3. Can be associated with concurrent hypercalcemia
4. Some breeds predisposed (e.g., miniature schnauzers, poodles)
5. Will not dissolve

C. Cystine
1. Radiolucent stone typically
2. Inborn error in metabolism, most commonly seen in dachshunds and English bulldogs
3. Can be dissolved using 2-mercaptopropionylglycine as well as a low-protein and alkalizing diet

D. Urate
1. Radiolucent stone typically
2. Can be associated with portosystemic shunts
3. Metabolic problem in liver and kidney tissues in some dogs, especially the Dalmatian
4. Can try to prevent with low-protein, alkalizing diet and allopurinol

E. Silicates
1. German shepherds are predisposed
2. Typically do not dissolve

F. Uroliths within the urinary bladder
1. Retrieved by ventral cystotomy
2. Always flush urethra to assure none are lodged there intraoperatively
3. Close in 1, 2, or 3 layers using appositional or inverting suture patterns
a. Use a monofilament absorbable suture material
b. Chromic catgut would not be appropriate

G. Urethral stones
1. Typically male dogs; stones lodge at the base of the os penis, dorsal to the ischium or within the prostatic urethra most commonly
2. Can present with urinary obstruction and be an emergency
a. Hyperkalemia: Most effective treatment is to reestablish urinary flow. Can also use insulin and glucose, calcium gluconate, and sodium bicarbonate to decrease potassium in an emergency
3. Performing a cystotomy is preferable to a urethrotomy, so attempt to flush the stones back into the bladder if possible
4. If cannot get stones back into the urinary bladder (rare), then perform urethrotomy or urethrostomy
a. Dogs: Scrotal urethrostomy is preferred location but can also perform a prescrotal, perineal (difficult in a dog), or prepubic procedure
b. Cats: Perineal or prepubic urethrostomy

IV. Bladder neoplasia
A. Most common tumor of the bladder is transitional cell carcinoma
1. Scottish terriers are over-represented
2. Canines: Females more commonly affected than males
3. In dogs, location is often associated with the trigone, often making surgical resection difficult. In cats, can be apical and lend itself to surgical resection
4. Possible link to exposure to chemicals. Also, linked with exposure to acrolein, which is a metabolite of cyclophosphamide
5. Diagnosis: Contrast radiographs, abdominal ultrasound can each delineate a mass in the bladder. Cytologic determination can be made from sediment from an acquired urine sample. In general, it is recommended that a traumatic catheterization is performed to obtain a sample. Cystocentesis is typically avoided due to concerns over potentially seeding the neoplasia else where. Abdominal ultrasound is useful for staging for metastatic disease as well. Can also metastasize to bone and lung, so chest radiographs are also recommended
6. Treatment: Can attempt surgical resection if it is located in an anatomic region that is amenable to surgical resection. Typically, therapy is

centered on piroxicam, which is a nonsteroidal antiinflammatory medication. Other medications used include cisplatin, carboplatin, mitoxantrone
7. Prognosis: Typically guarded to poor as often metastatic at the time of diagnosis

SURGICAL DISEASES OF THE GENITAL TRACT

I. Intersex malformations
 A. Hermaphrodite: Possess both male and female gonadal tissue
 B. Pseudohermaphrodite: Possess only one gonadal tissue, but external genitalia has some characteristics of the opposite sex
II. Diseases of the male genital tract
 A. Prostatic neoplasia
 1. Most commonly adenocarcinoma or transitional cell carcinoma
 2. Incidence of prostatic neoplasia is not affected by castration
 3. Treatment: Can attempt a prostatectomy, but urinary incontinence is reported to be a serious side effect. Prognosis is poor
 B. Benign prostatic hyperplasia
 1. Occurs due to androgenic stimulation under control of the testicles
 2. Prostate enlarged and may interfere with urination or defecation
 3. Rectal examination reveals a large, firm prostate that is typically nonpainful and symmetrical
 4. Treatment: Castration is the most effective treatment. Can attempt estrogen therapy in cases where owners will not castrate
 C. Prostatic abscesses
 1. Serious medical disease
 2. Diagnosis: Enlarged and painful prostate, typically asymmetrical
 3. Treatment: Stabilization and surgical exploration. Lance abscess and omentalize. Place drains or marsupialize the abscess
 4. Prognosis: Guarded, 25% perioperative mortality rate
 D. Cryptorchidism
 1. Diagnosis: History if owner has possessed the dog or cat since a young age and has complete medical and surgical history of the animal. If not, can conduct hormonal assays to detect androgen levels suggestive of the presence of testicular tissue. In cats, can simply examine the penis for spikes on the base of penis, which would indicate retained testicular tissue
 2. Medical importance: Potentially unwanted breedings as well as significantly increased incidence of testicular neoplasia in cryptorchid testes compared with scrotal testes
 3. Locate testicle and remove
 E. Testicular tumors
 1. Sertoli cell tumor: Secrete estrogens and can have signs of hyperestrogenism, which include bilaterally symmetrical alopecia, gynecomastia, swollen prepuce, myelotoxicosis, male dog attraction, penile atrophy, and squatting posture during urination
 a. Diagnosis: Testicular mass or signs of hyperestrogenism
 b. Treatment: Castration
 c. Prognosis: Favorable; does metastasize more than other testicular tumors, but metastatic disease is still rare
 2. Interstitial (Leydig) cell tumor: Secrete testosterone so may predispose to benign prostatic hyperplasia, perianal adenoma, or perineal hernias. Typically small and benign tumors. Treatment via castration yields an excellent prognosis
 3. Seminoma: Benign growth of germinal epithelium. Castration gives excellent prognosis
 F. Phimosis: Inability of the penis to protrude from the preputial orifice
 G. Paraphimosis: Inability of the penis to retract back within the prepuce
III. Diseases of the female genital tract
 A. Ovarian remnant
 1. Can occur after ovariohysterectomy
 2. Signs of estrus behavior post spaying
 3. Diagnosis: Clinical signs; can run estrogen and progesterone assays; abdominal ultrasound may also show cystic ovarian remnant
 4. Treatment: Excise remnant tissue
 5. Prognosis: Excellent if all tissue removed
 B. Ovarian tumors are rare, owing to the common procedure of performing ovariohysterectomy early in life
 C. Cystic endometrial hyperplasia or pyometra complex
 1. Develops during diestrus: Corpora lutea forms and secretes progesterone. This progesterone increases uterine glandular secretions and decreases myometrial contractions
 2. Clinical signs can include discharge through the vulva, lethargy, vomiting, anorexia, polyurina or polydipsia resulting from endotoxemia, signs of sepsis, or abdominal distension. *Escherichia coli* is most commonly the causative organism
 3. Classically two types: Open vs. closed. In the open type, the cervix is open, allowing drainage to occur. In the closed type, the cervix is closed, and drainage is not occurring. Typically, closed pyometra is a more serious disease than open pyometra, but both are serious
 4. Diagnosis: Typically clinical diagnosis. Survey radiographs reveal a fluid opacity between the bladder and colon that can displace a considerable amount of tissues within the abdomen. CBC typically shows a leukocytosis with a left shift, but not always. Can be febrile, hypothermic, or normothermic. Serum chemistry panel may show azotemia from endotoxic renal damage or dehydration. Vaginal cytology reveals septic purulent exudate

5. Treatment: Ovariohysterectomy is the treatment of choice. Always immediately on stabilization in a closed pyometra, timing of surgery is debated in open pyometra. If owners want to breed, can attempt to lyse corpora lutea via prostaglandin F-2α and antibiotics, but eventual recurrence is very common with this therapy

D. Cesarean section
 1. Indicated in situations of dystocia, including no birth despite strong contractions for longer than 30 minutes, weaker straining for longer than 2 hours, no birth for more than 4 hours, retained baby lodged in vulva, any signs of toxicity, or signs of fetal distress (e.g. decreased heart rate, decreased motion)
 2. Surgical emergency: Traditional approach, then hysterotomy to access puppies or kittens
 3. Can be due to maternal factors such as uterine inertia, abnormal vaginal conformation, decreased pelvic canal size. Can also be due to fetal factors such as large head confirmation (especially brachycephalic breeds), fetal monsters, fetal malposition. It is normal and acceptable for puppies and kittens to be born in the breech position
 4. More common in small and brachycephalic breeds

SURGICAL DISEASES OF THE RESPIRATORY TRACT

I. Diseases of the upper respiratory tract
 A. Brachycephalic airway syndrome
 1. Seen in brachycephalic breeds as a result of conformational anatomy of head and nose
 2. Components include stenotic nares, elongated soft palate, everted laryngeal saccules, and in some dogs can lead to laryngeal collapse. English bulldogs can also concurrently have a congenitally hypoplastic trachea, exacerbating their disease
 3. Signs attributable to progressive inspiratory dyspnea, decreased tolerance to exercise; can collapse
 4. Diagnosis: Often a clinical diagnosis. Chest radiographs should be obtained to examine for noncardiogenic pulmonary edema, cor pulmonale, hiatal hernia, or aspiration pneumonia. Dogs most often have to be heavily sedated or anesthetized to examine the soft palate and laryngeal structures. The soft palate should just cover the tip of the epiglottis normally
 5. Treatment: Resection of excessive nasal tissue, shortening of the soft palate, removal of the laryngeal saccules
 6. Prognosis is favorable, but postoperative swelling can cause significant dyspnea and these patients should be monitored closely
 B. Nasopharyngeal polyps
 1. Inflammatory polyps arising from the middle ear
 a. Can course through the eustachian tube and enter the nasopharynx, causing inspiratory dyspnea, sneezing, nasal discharge
 b. Can alternately or concurrently exit through the tympanic membrane and enter the external ear canal, causing signs of otitis externa or aural irritation and discharge
 2. Most commonly occur in young cats. Abyssinian cats are overrepresented. Potentially a history of chronic upper respiratory infections before the polyp appears
 3. Diagnosis: High index of suspicion based on clinical signs and patient signalment. Radiographs may reveal material within the tympanic bulla(e) unilaterally or bilaterally. Otoscopic examination or nasopharyngeal examination may reveal a polyp
 4. Treatment: Removal of the polyp via a ventral bulla osteotomy is very effective in curing this disease with a less than 2% recurrence rate. An alternative therapy involves manual traction of the polyp to remove it; recurrence rates are higher with this therapy but decrease to approximately 25% when prednisone therapy is added
 5. Prognosis: Excellent
 C. Laryngeal paralysis
 1. More common in dogs than in cats. Two forms: Somewhat rare congenital form, which has been described in breeds including the Siberian husky, Bouvier des Flanders, dalmatian, bull terrier, and rottweiler. The acquired form is much more common and typically affects large-breed middle-aged to older dogs. Labrador retrievers are overrepresented. Underlying cause of laryngeal paralysis is dysfunction of the recurrent laryngeal nerve. Almost routinely bilateral in dogs with clinical signs
 2. Clinical signs: Inspiratory stridor, change in phonation, coughing, exercise intolerance, collapse, cyanosis. Can be linked with other diseases, including myasthenia gravis, polyneuropathy, polymyopathy, neoplasia in the mediastinum or neck, trauma, or hypothyroidism. Can be in severe compromise when present, in which case oxygen supplementation, IV access, active cooling, sedatives, and possibly steroids are helpful
 3. Diagnosis: Requires heavy sedation or light anesthesia to confirm diagnosis. Failure of arytenoid cartilages to abduct during inspiration. Often cartilages are inflamed and edematous. Thoracic radiographs are indicated to rule out aspiration pneumonia, megaesophagus, or metastatic disease if neoplasia is involved
 4. Treatment: Most commonly an arytenoid lateralization procedure ("tie-back") is performed. Briefly, the muscular process of one of the arytenoid cartilages is mobilized and sutured to either the cricoid or thyroid cartilage. This abducts the arytenoid cartilage in the lumen of the larynx
 5. Prognosis: Favorable with idiopathic form. If underlying disease exists, then prognosis is dependent on that disease

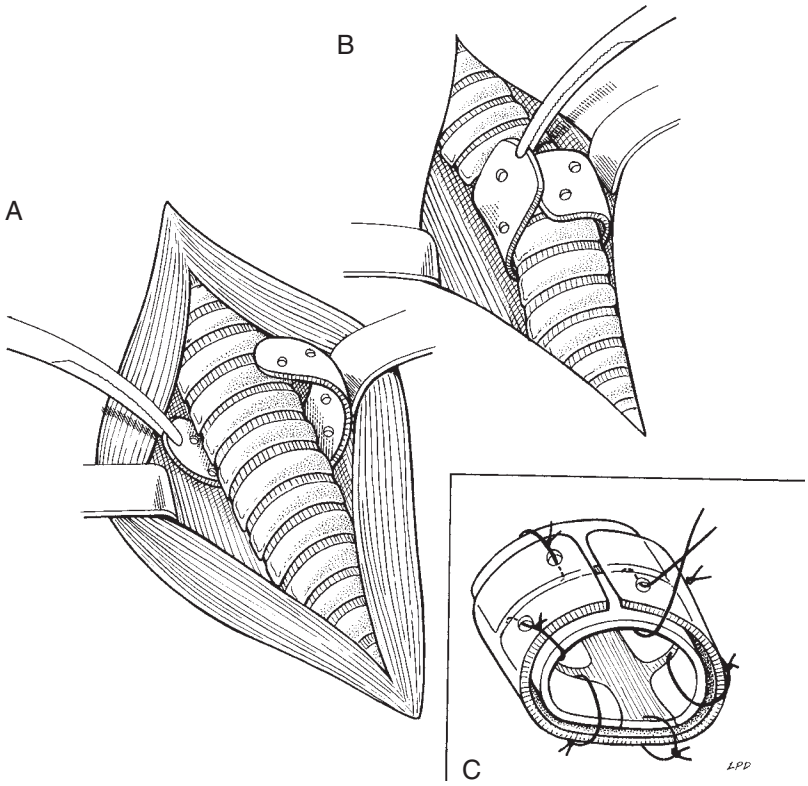


Figure 27-5 **A,** To place prosthetic rings on the trachea, dissect a tunnel around the trachea at each implantation site and then guide the prosthesis through the tunnel. **B,** Rotate the prosthesis around the trachea. **C,** Secure the prosthesis with several sutures. (From Fossum TW et al. *Small Animal Surgery*, 3rd ed. St Louis, 2007, Mosby.)

D. Tracheal collapse: Caused by progressive chondromalacia of the cartilages of the trachea
 1. Signalment: Typically small- or toy-breed, middle-aged, overweight dogs
 2. Clinical signs: Exercise intolerance, wheezing, hacking, "goose honk" cough often can be elicited by tracheal manipulation and is the classic sign ascribed to this disease. Dyspnea classically is inspiratory if involving the extrathoracic trachea and expiratory if involving the intrathoracic portion
 3. Diagnosis: Radiographs my capture the collapse, but disease is often dynamic and fluoroscopy is useful. Tracheoscopy can also be performed
 4. Treatment
 a. Medical management: Weight loss, harness instead of neck leads, antibiotics, bronchodilators, corticosteroids, antitussives, sedatives, exercise restriction, and supplemental oxygen as well as environmental control of pollutants is recommended. Typically used for dogs with less than 50% loss of luminal cross section
 b. Surgical management: Can place intraluminal stents made of metallic implantable mesh; can also suture polypropylene rings to outside of tracheal rings in an effort to provide additional stiffness (Figure 27-5)
 5. Prognosis: Guarded to fair

E. Lung tumors
 1. Metastatic disease is more common than are primary lung tumors in dogs and cats. Primary lung tumors in dogs and cats are typically malignancies and most frequently involve the diaphragmatic lobes of the lungs
 2. Presenting signs: Coughing, dyspnea, anorexia, vomiting. Can also be present with signs attributable to hypertrophic osteopathy
 3. Diagnosis: Typically derived from thoracic radiographs. Solitary lung tumors are consistent with a primary lung tumor, whereas multiple masses are more consistent with metastatic disease. FNA of the masses can be attempted
 4. Treatment: Lung lobectomy for primary lung tumor.
 5. Prognosis: Depends on stage of disease but typically poor long term. Median survival times can reach close to one year if patient lacks nodal involvement

Supplemental Reading

Bojrab MJ. *Current Techniques in Small Animal Surgery*, 4th ed. Baltimore, 1998, Lippincott Williams & Wilkins

Fossum TW. *Small Animal Surgery*, 3rd ed. St Louis, 2007, Mosby.

Slatter D. *Textbook of Small Animal Surgery*, 3rd ed. Philadelphia, 2003, Saunders.

28 CHAPTER

Urinary System Disorders

Dennis J. Chew

GENERAL INFORMATION

I. Upper urinary tract: Renal parenchyma, renal pelves, and ureters. Lower urinary tract: Bladder and urethra. Useful for diagnosis, prognosis, and treatment to decide how much of a urinary tract disease involves the upper urinary tract, lower urinary tract, or both
II. Upper urinary tract disorders: Chronic renal failure (CRF), acute renal failure (ARF), upper urinary tract infection (UTI), renal neoplasia, renal pelvic or ureteral obstructions, and renal bleeding
III. Lower urinary tract disorders: Bacterial UTIs, idiopathic cystitis of cats, urethral obstruction, urinary incontinence, and neoplasia of the bladder and urethra
IV. In general, animals are more likely to be sick from upper urinary tract disorders compared with those of the lower urinary tract unassociated with urinary obstruction

UPPER URINARY TRACT DISORDERS

I. Renal failure (general)
 A. Excretory renal failure exists when blood urea nitrogen (BUN) and serum creatinine are above the upper normal range (*azotemia*). Decide whether azotemia is prerenal, primary renal, or postrenal
 1. *Prerenal azotemia* occurs when perfusion is reduced and nitrogenous waste accumulates in blood
 a. Causes include dehydration, shock, congestive heart failure (CHF)
 b. Urine should be highly concentrated. Urinary specific gravity (USG) is expected to be greater than 1.030 in dogs and 1.040 in cats
 c. Urine sediment is normal; kidney size normal
 2. Postrenal azotemia
 a. Causes are leakage of urine into retroperitoneal or peritoneal cavities or from obstruction to outflow from both kidneys
 b. USG is variable. Urinary sediment may be active with red blood cells (RBCs) or white blood cells (WBCs)
 c. Imaging is necessary for diagnosis
 3. Primary renal azotemia is due to renal parenchymal lesions, either acute or chronic
 a. Urine cannot be highly concentrated. USG less than 1.030 in dogs and less than 1.040 in cats is expected at the same time as the azotemia
 b. Urine sediment may show casts, WBCs, and proteinuria
 B. Magnitude of azotemia does not distinguish prerenal, primary renal, or postrenal causes. USG is the most important factor to evaluate. Imaging is also usually necessary
II. Chronic renal failure (CRF)
 A. CRF occurs with permanent loss of at least 75% of functional nephron mass as a result of chronic lesions (nephron dropout, fibrosis, tubulointerstitial nephritis [TIN]). Increased serum phosphorus is observed after 85% of nephron mass has become nonfunctional
 B. Cause is usually idiopathic. Probably due to glomerular injury
 C. Any age, breed, or sexual status can be affected. Risk is low for younger animals and higher for older animals. Incidence increases in those older than 10 years
 D. CRF in young animals: Usually familial nephropathy or renal injury from infection or toxins. Cats rarely have familial nephropathy except for renal amyloidosis in Abyssinians and Oriental shorthairs
 E. Causes of CRF: Dogs and cats
 1. Chronic TIN of unknown cause (most common pathologic diagnosis)
 2. Chronic pyelonephritis (can be difficult to distinguish histologically from TIN)
 3. Chronic glomerulonephritis (can be difficult to distinguish histologically from TIN)
 4. Amyloidosis (familial in shar-pei dogs and Abyssinian cats)
 5. Polycystic kidney disease (familial in Persians)
 6. Hypercalcemic nephropathy
 7. Chronic obstructive uropathy (hydronephrosis)
 8. Familial renal disease
 9. Progression after ARF
 10. Chronic toxicity (e.g., food-associated, drugs, environmental toxins)
 11. Neoplasia (e.g., renal lymphoma)
 12. Pyogranulomatous nephritis from feline infectious peritonitis (cats)

13. Hypokalemic (kaliopenic) nephropathy (cats)
14. Chronic toxicity (e.g., food-associated, drugs, environmental toxins)
15. Primary systemic hypertension

F. Familial renal diseases of dogs and cats
1. Amyloidosis: Abyssinian, Siamese, Oriental shorthair cat, beagle, English foxhound, shar-pei
2. Unilateral renal agenesis: Beagle
3. Glomerulopathy (basement membrane disorder): Beagle
4. Tubular dysfunction (Fanconi syndrome): Basenji
5. Tubular dysfunction (renal glucosuria): Norwegian elkhound
6. Periglomerular fibrosis: Norwegian elkhound
7. Basement membrane disorder: Bull terrier, dalmatian, Doberman pinscher, English cocker spaniel, Samoyed, Texas NAV dogs, rottweiler
8. Polycystic kidney disease: Bull terrier, Cairn terrier, West Highland white terrier, Persian cat
9. Membranoproliferative glomerulonephritis: Bernese mountain dog, soft-coated Wheaten Terrier, Brittany spaniel
10. Renal dysplasia: Soft-coated wheaten terrier, Alaskan malamute, chow chow, golden retriever, Lhasa apso, shih-tzu, miniature schnauzer, standard poodle
11. Multiple renal cystadenocarcinomas: German shepherd dog
12. Renal telangiectasia: Pembroke Welsh corgi

G. Diagnosis
1. Azotemia, submaximally concentrated urine; reduction in kidney size, irregular kidneys, nephrocalcinosis, nonregenerative anemia, chronic failure to thrive (loss of body condition, muscle mass, hair coat quality), anorexia, vomiting, depression, weight loss
2. Renal biopsy findings: Not specific
3. Renal biopsy: Not indicated in those with small kidneys

H. Progressive chronic kidney disease (CKD) eventually results in CRF
1. CKD can be discovered before CRF in those in which kidney size progressively decreases, renal mineralization progressively increases, urine concentration declines from maximal values, and proteinuria increases
2. Once a certain nephron mass has been lost from CKD, a progressive self-destructive cascade of events happens in the remaining healthier kidney that eventually results in further nephron damage (glomerulosclerosis and TIN)
3. Progressive self-propagating destruction of the chronically damaged kidney involves glomerular hypertension and glomerular hyperfiltration
4. Other mechanisms for progressive destruction: Renal mineralization and damage from uncontrolled renal secondary hyperparathyroidism

I. Treatment
1. Very little evidence exists to make decisions about treatment of CKD cases that are not yet azotemic. Nearly all of our data about treatment come from dogs and cats that are obviously azotemic
2. Dietary therapy
 a. Feed a renal diet; not been determined whether this is helpful if not azotemic. May increase survival and extend the time between uremic crises
 b. The two major factors of benefit: Phosphorus restriction and omega-3 supplementation
 c. Protein restriction as the sole change does not protect the kidney from progression or extend the life of the dog or cat with CRF; does not reduce the workload of the kidney. Dietary protein restriction with adequate caloric intake reduces BUN, which may parallel clinical signs of uremia in some patients
 d. Dietary phosphate restriction may be adequate treatment to control serum phosphorous and (PTH) concentrations in those with early CRF
3. Intestinal phosphate binders
 a. Often needed to gain optimal control of serum phosphorus and serum PTH. Goal: To provide a compound that binds to intestinal phosphate, prevents its absorption, and increases its fecal excretion
 b. Aluminum salts (hydroxide, carbonate): Mainstay treatment
 c. Calcium salts (carbonate, acetate): Developed in human medicine to avoid toxicity from aluminum accumulation; sometimes used
 d. Newer-generation medications: Sevelamer HCl and lanthanum carbonate have not yet achieved mainstream use
 e. Epakatin: Veterinary product marketed for use in cats with CRF. Decreases serum phosphorus in normal cats. Reported to decrease digestibility of phosphorus in the diet
 f. Phosphate binders work best when given with food or within 1 to 2 hours of food ingestions
4. Antacids
 a. Gastric hyperacidity: Presumed to contribute to gastric erosions, nausea, and vomiting during CRF. Increased circulating gastrin has been documented to occur in dogs and cats with CRF as a result of decreased renal degradation of gastrin
 b. Histamine (H_2) receptor blockade (e.g., famotidine, ranitidine): Usually helpful first-line treatments
 c. Proton pump blockade (omeprazole) provides an option either instead of or when H_2 blockade is not effective

5. Angiotensin-converting enzyme (ACE) inhibition
 a. Proven beneficial in treatment of protein-losing nephropathy; will likely achieve standard of care status for all progressive CKD
 b. Renoprotective effects: Independent of effects to control systemic blood pressure; lowers intraglomerular hypertension caused by lowering the tone of the efferent glomerular arteriole (analogous to afterload reduction for the heart). Also reduces angiotensin II and aldosterone (which increase adverse tissue healing in damaged kidneys)
 c. Enalapril, benazepril, lisinopril, and imidapril have similar effects. Enalapril and benazepril are most commonly used
 d. Excess lowering of efferent arteriolar tone results in emergence of azotemia or worsening of azotemia in those with CRF. Systemic blood pressure and renal function testing should be performed before and periodically following ACE inhibitor treatments
6. Calcitriol therapy
 a. Proven benefit for survival in dogs
 b. Main effect of calcitriol for patients with CRF: Decreased synthesis of PTH through genomic effects in the parathyroid gland. Excess PTH is toxic to a variety of tissues, including the kidneys
 c. Calcitriol: Dosed to the effect on ionized calcium and PTH status. Doses from 2.5 to 3.5 ng/kg once daily are usually sufficient to lower PTH without increasing serum ionized calcium; can do intermittent dosing with 9 ng/kg twice weekly (every 3.5 days)
 d. Serum phosphorus should be controlled to less than 6.0 mg/dL before calcitriol treatment can be safely started
7. Control of systemic hypertension
 a. Important to prevent end-organ damage (eyes, brain, kidney)
 b. Uncontrolled hypertension transmits excessive pressure to the glomerular capillary beds. Increased pressure contributes to glomerular hypertension and hyperfiltration, which further damages nephrons
 c. ACE inhibitor: Choice for dogs, although monotherapy at the usual dose is often not effective (0.5 to 1.0 mg/kg twice daily). Increasing doses of ACE inhibitor or addition of amlodopine are provided to effect as monitored by serial measurement of blood pressure
 d. Amlodopine: Drug of choice for control of systemic hypertension in cats. Most often, 0.625 mg/cat/day is safe and effective
8. Potassium salt treatment: Assess potassium status periodically (especially cats). Give potassium salts if there is persisting hypokalemia
9. Azodyl: Recently launched in the veterinary market
 a. Probiotic (oral) given daily to maintain a population of colonic bacteria that metabolize nitrogenous waste
 b. BUN and serum creatinine decreased in a study of a small number of cats receiving this treatment; long-term effects on progression of CRF have not been reported
10. Kremezin: Japanese product for treatment of cats with CRF. Contains granules of activated charcoal that provide nonselective adsorption of uremic toxins from the GI tract

J. Prognosis
 1. Progression of CKD and CRF: Variable; slower in cats than in dogs. Many cats with CRF live for months to years. Dogs with CRF on occasion live years, but up to a year is more common with first-line treatments of diet
 2. Serial analysis of serum creatinine, phosphorus, PTH, albumin, body weight, systemic blood pressure, and patient history: Necessary to determine success of treatment and disease progression

III. Acute primary (intrinsic) renal failure (AIRF)
 A. AIRF: Syndrome when there has been loss of more than 75% of nephron mass, at least temporarily. Differs from CRF; possibility for healing of lesions of AIRF with recovery of renal function in some instances
 1. Increased serum phosphorus often occurs early in the development of AIRF, unlike that of CRF, in which increases in PTH provide a protective lowering of serum phosphorus as nephron mass gradually proceeds
 2. Progressive azotemia with or without oliguria develops as the result of some combination of vasoconstriction of the afferent arteriole, increased tubular pressure from intratubular obtruction or extraluminal compression, tubular backleak, or failure to filter due to changes in the character of the glomerular filter
 B. Renal lesions of AIRF
 1. Classically acute tubular necrosis (ATN); spectrum of necrosis to subtle degeneration. ATN is secondary to either ischemic or nephrotoxic causes
 2. Acute interstitial nephritis also can create AIRF secondary to infectious causes (allergic reaction rarely). Acute interstitial nephritis in dogs is classically associated with leptospirosis
 C. Ischemic causes of ATN and AIRF
 1. Systemic hypotension is not necessary for the development of tubular lesions. Renal blood supply determines if lesions develop
 2. Causes include dehydration, trauma, anesthesia, sepsis, heat stroke, pigment nephropathy (hemolysis from immune-mediated hemolytic anemia, coral snake envenomation, bee sting, myoglobinuria), ACE inhibitors, shock, hemorrhage, surgery, burns, hypothermia, nonsteroidal antiinflammatory drugs (NSAIDs), acute papillary necrosis (medullary renal amyloidosis, Fanconi syndrome)
 D. Nephrotoxins
 1. True nephrotoxin: Compound capable of creating renal tubular cell membrane injury directly

2. Nephrotoxicant: Describes acute renal injury or AIRF following the effects of a chemical compound, whether the injury is direct or indirect from the agent. For example, NSAIDs are nephrotoxicants and not nephrotoxins because they require systemic hypotension to create AIRF
3. Nephrotoxic causes of ATN
 a. Ethylene glycol (EG)
 b. Antimicrobials: Aminoglycosides, amphotericin-B, sulfonamides administered to a dehydrated patient, Tetracyclines administered intravenously (IV), Nafcillin administered intraoperatively
 c. Easter Lily ingestion (cats)
 d. Grape or raisin toxicity (dogs)
 e. Hypercalcemia and hypercalciuria
 f. Cholecalciferol rodenticide (Quintox, Rampage)
 g. Calcipotriene (Dovonex)
 h. Anticancer drugs: Cisplatin, high-dose doxorubicin (Adriamycin), radiocontrast agents administered IV, heavy metals (e.g., zinc, arsenic, lead), hydrocarbons
 i. Fluorinated inhalation anesthetics
 j. Calcium edetate
 k. Mycotoxins (e.g., ochratoxin, citrinin)

E. AIRF: Three classic phases—latent or incipient phase, maintenance, and recovery
1. Latent phase: Time from initial exposure to the nephrotoxin or ischemic event until there is evidence for renal injury (cylindruria, renal epithelial cyturia, renal tubular enzymuria, submaximal urine concentration, decreased glomerular filtration rate [GFR] before azotemia)
 a. Animals in this phase are usually asymptomatic and will be discovered only if there is suspicion for the development of AIRF while in the hospital and being treated with drugs with known nephrotoxic potential
 b. Removal of the inciting cause stops further renal injury
2. Maintenance phase: Develops after a critical mass of lethal renal cell injury has occurred
 a. Azotemia has developed by this time and does not immediately respond to correction of dehydration or volume expansion
 b. Removal of the inciting phase does not result in correction of azotemia
 c. This is a fixed phase of excretory renal failure that can last 1 to 3 weeks, or it may last forever (when no healing occurs)
 d. Some will be oliguric or anuric (e.g., EG intoxication); others may have polyuria (e.g., aminoglycoside intoxication)
3. End of maintenance phase: When the patient dies or is euthanized, returns to normal renal function based on BUN and creatinine, or heals as a renal cripple with CRF of varying magnitude
 a. Some patients return to a normal BUN and creatinine. GFR may still be lower than normal if measured
 b. Maximal ability to concentrate urine may or may not be restored

F. Treatment
1. Most important aspect of treatment: Optimal IV fluid therapy. With inadequate fluid therapy, the kidneys do not receive enough perfusion, allowing the development of further lesions of ATN from ischemia. Excess fluid therapy results in development of overhydration, CHF, pulmonary edema, and death
 a. Measurement of urine output is imperative during the first 24 to 48 hours
 b. Normal urine output is 0.5 to 1.0 mL/kg/h; if on IV fluids, 2.0 to 5.0 mL/kg/h is expected. Less than 2 mL/kg/h defines oliguria in patients on IV fluids
2. If oliguria or anuria persists after correction of dehydration, increase urine flow using some combination of mannitol, furosemide, or dopamine
3. If urine flow is not increased after diuretic treatments, stop diuretics and decrease IV fluids to avoid the development of overhydration and allow time for natural healing and resolution of AIRF if possible
4. Dialysis improves prognosis for survival and renal recovery; early rather than late dialysis treatments are more effective in providing a beneficial outcome. Hemodialysis is available at a few regional centers in the United States; peritoneal dialysis is more widely available and less expensive

G. Prognosis varies with the specific cause of the AIRF. In general, the higher the level of the azotemia during the maintenance phase, the poorer the prognosis. Overall, leptospirosis has the best prognosis for survival and recovery of normal renal function; EG cases with azotemia and oligoanuria have the worst prognosis.

H. EG intoxication
1. Occurs following ingestion of 4 to 13 mL/kg in dogs and 1.5 mL/kg in cats; can be lethal. EG is transformed to cytotoxic metabolites in the liver by alcohol dehydrogenase. The half-life of EG is less than 12 hours in dogs and considerably shorter in cats
2. Diagnosis is based on observation of ingestion, finding a source for possible ingestion, and acute onset of alcohol-like inebriation. Painful kidneys and muscles may be detected on physical examination. Finding some combination of metabolic acidosis that may be severe, hyperphosphatemia out of proportion to the azotemia observed, high anion gap, and very high osmole gap are highly supportive for the early diagnosis of EG toxicity. A positive colorimetric reaction on the EG test kit (in-house method) provides convincing evidence for this diagnosis. Chromatographic techniques are available for definitive diagnosis using blood and urine samples, but it usually takes days to get results
3. Polyuria and polydipsia can be intense shortly after ingestion of EG and are often followed by development of oliguria and then anuria that persists despite all treatments

4. Azotemia may take greater than 24 hours to develop from renal lesions; prerenal azotemia may be apparent earlier (vomiting, obligatory polyuria from EG excretion)
5. Treatment
 a. In dogs, 4-methylpyrazole (4-MP) is the definitive antidote for treatment *before* EG has been completely metabolized. 4-MP antagonizes the activity of alcohol dehydrogenase, which lessens biotransformation of EG to toxic metabolites. Effective after ingestion of a lethal dose up to at least 5 hours in most dogs and up to 8 hours in many. After 8 hours following ingestion, most EG has been transformed to its toxic compounds
 b. Cats require much higher doses of 4-MP than dogs; sedation is a side effect at these high doses
 c. Ethyl alcohol: Antidote of choice before 4-MP was developed in both dogs and cats; competes with EG for metabolism by alcohol dehydrogenase. Severe depression from ethyl alcohol is a major side effect; it also adds to dehydration. Respiratory depression can cause death
 d. Hemodialysis of dogs for 6 to 9 months has been effective for recovery of renal function in some dogs that were anuric. Prognosis for survival in anuric patients without access to dialysis is near zero

I. Leptospirosis
1. Leptospirosis is a systemic disease of dogs that can cause AIRF from acute to subacute interstitial nephritis. Infection usually follows mucosal penetration of organisms from drinking water that has been contaminated with urine from infected carriers
2. Vaccination against serovars canicola and icterohemorrhagiae has greatly lessened clinical disease with these serovars. Clinical syndromes are usually due to "atypical" serovars, in which vaccines have not been administered to most dogs (pomona, grippotyphosa, Bratislava in the United States)
3. Encroachment of wildlife into suburban living spaces accounts for infections with atypical serovars; exposure to farm animals also accounts for infection with some serovars
4. Infections with serovars canicola and icterohemorrhagiae classically have changes in liver enzymes at the same time renal failure is discovered. Atypical serovars do not typically increase liver enzymes; if elevated, liver enzymes may not be increased at the same time as increased BUN or creatinine
5. Oliguria initially is prerenal as a result of systemic effects of the infection; as renal lesions accrue, oliguria from primary renal mechanisms predominate. Urinary concentration is initially high and becomes progressively less concentrated. USG is often in the isosthenuric range when AIRF is diagnosed
6. Treatment
 a. Penicillin: Drug of choice to eliminate leptospiral organisms from most of the body; doxycycline is the treatment of choice to rid dogs of the renal carrier state.
 b. Supportive treatment with IV fluids for 1 to 2 weeks in addition to penicillins. Short-term dialysis may be needed in those with oligoanuria and high-level azotemia
7. Prognosis is generally good for AIRF secondary to leptospiral infection when penicillins are started early enough

J. Parenteral antibiotics
1. Occasionally cause AIRF from ATN. All IV antibiotics can at times cause AIRF, especially when given rapidly at high doses. Aminoglycoside toxicity is most common; most reports are from gentamicin in dogs or cats, but all aminoglycosides are nephrotoxic and capable of inducing AIRF
2. Aminoglycoside nephrotoxicity has become less common because of the development of the fluoroquinolones for treatment of serious bacterial infections
3. Aminoglycosides are prescribed in complicated medical conditions, often those that are life-threatening
4. Giving the total daily dose of aminoglycoside once daily rather than in divided doses reduces renal exposure to this nephrotoxin. This method of dosing may contribute to the decreased incidence of aminoglycoside nephrotoxicity
5. A "cast watch" can be useful to detect renal damage before BUN and creatinine increase; reduction in USG and increases in excretion of urinary enzymes also precede increases in BUN and serum creatinine

K. Lily intoxication
1. Creates a specific syndrome of AIRF in cats, but not in dogs. Indoor cats are particularly attracted to this plant
2. All parts of the lily are toxic, and only a small part need be eaten for the nephrotoxic effects to be seen. Detection of plant pieces in vomitus or feces should increase the suspicion for lily toxicity
3. Severe azotemia and oligoanuria can be seen in this form of AIRF. Despite massive azotemia, some cats have recovered with medical treatment for several weeks
4. There is no antidote; the specific toxin has yet to be isolated

L. Raisin or grape ingestion
1. Cause AIRF in dogs with or without hypercalcemia; toxicity not reported in cats
2. Gastric decontamination is recommended, even for small amounts if there are GI signs
3. Dehydration from GI signs is common: IV fluid support may be needed for up to 1 week, longer if already in renal failure. Prognosis is fair to good when supportive treatment instituted early
4. No antidote available; the toxic principle is not known

M. NSAID ingestion
1. Overdose or accidental ingestion can create AIRF but only if vasoconstrictor signals have been activated by the body's perception of volume contraction. Volume contraction from whatever cause increases release of norepinephrine and angiotensin II as well as activation of the sympathetic nervous system to cause vasoconstriction, which increases core blood pressure. This same vasoconstrictive response happens in the kidneys, but this effect is normally blunted by the kidney's synthesis of vasodilatory prostaglandins. NSAIDs block the ability of the kidney to protect itself by producing vasodilatory prostaglandins; the net effect favors vasoconstriction that can be severe enough to create ATN and AIRF
2. Ingestion of NSAIDs can create hypotension following GI bleeding from ulcers in some instances. Absorption of NSAID blocks synthesis of renal vasodilatory prostaglandins at the time vasoconstrictor signals have been activated
3. AIRF can be prevented following toxic NSAID ingestion by ensuring euvolemia until the NSAID is cleared and renal effects abate. This usually means 2 to 3 days of IV fluids to ensure renal perfusion

N. Hypercalcemia
1. Hypercalcemia that is severe and rapid in development can create AIRF; usually occurs following exposure to vitamin D or its metabolites
2. Ingestion of rat-bait poison containing cholecalciferol or antipsoriasis creams containing the potent calcitriol analogue calcipotriene can cause hypercalcemia
3. Cholecalciferol toxicity can be confirmed by finding very high concentrations of 25-hydroxyvitamin D
4. Calcipotriene toxicity is diagnosed on history; there is no vitamin D metabolite test available to test for its presence

IV. Upper UTI
A. Pyelonephritis occurs with the same bacterial organisms that create lower UTI (see section below). *Escherichia coli* is the most common and important organism
B. Pyelonephritis is much more commonly a chronic rather than acute condition
C. Fever, renal pain, leukocytosis, leukocyturia, positive urine culture, dilatation of the renal pelvis, or diverticulae in some combination will support the diagnosis
D. Infections without predisposing conditions of anatomy, function, or metabolism are unusual

V. Obstructive nephropathy
A. Refers to anatomic and functional effects on the kidneys
B. Causes
1. Obstruction of ureter and kidney from lesion in bladder trigone is common
2. Ureteral urolithiasis is occasional, especially in cats
3. Blood clots in ureter from a bleeding renal lesion are uncommon
4. Neoplasia of the renal pelvis can rarely create urinary outflow obstruction
5. Iatrogenic obstruction from a ligature around ureter is rare

C. Acute obstruction of one kidney does not result in azotemia if the kidneys were healthy before the obstructing process
D. Acute obstruction of both kidneys does result in azotemia if the obstruction is complete. Not compatible with life for more than 3 to 5 days
E. Partial obstruction to one or both kidneys results in hydroureter and hydronephrosis

VI. Renal neoplasia
A. Primary tumors of the kidney are more common than metastases to kidneys. Malignant tumors are far more common than benign ones
1. Adenocarcinoma of the renal tubule is the most common renal neoplasm in dogs
2. Renal lymphosarcoma (LSA) is most common in cat, usually bilateral
3. Transitional cell carcinoma can arise from the renal pelvis and cause obstruction or renal bleeding
4. Renal lymphoma is usually bilateral in cats and often the only organ identified with the tumor initially. Often lymphoma is in the GI tract and bone marrow. Half of cats have been noted to be feline leukemia virus positive. Can be in excretory renal failure, depending on how much of both kidneys are infiltrated with neoplastic cells. Fine-needle aspirate and cytology of affected kidney(s) is often diagnostic
5. Bilateral renal cystadenoma occurs in German shepherds, usually in association with generalized nodular dermatofibrosis and uterine leiomyoma. It is an autosomal dominant trait. Prognosis is poor and death is usually due to renal failure or metastatic disease
6. Other less common primary tumors include adenoma, fibrosarcoma, and hemangiosarcoma

B. Painless hematuria is a common clinical sign
C. Renal adenocarcinoma often presents with a polar mass lesion detected on palpation or renal imaging. Polycythemia is sometimes detected as a paraneoplastic syndrome. Metastases are common to the other kidney and to other sites. May present for hematuria, discovered fortuitously, or discovered during workup of metastases to other sites. Not azotemic, as only one kidney is obviously involved at time of diagnosis
D. Nephrectomy is the treatment of choice for unilateral renal neoplasia
E. LSA can respond favorably to standard chemotherapy protocols

LOWER URINARY TRACT DISORDERS (LUTD)

I. Bacterial UTIs
 A. Introduction
 1. Bacteria: *E. coli* accounts for more than half of UTIs in dogs and cats. *Staphylococcus* and *Proteus* spp. are common in dogs; *Enterococci, Enterobacter, Klebsiella*, and *Pseudomonas* spp. are less common
 2. Cats younger than 10 years of age rarely develop UTI unless they have an underlying urinary concentrating defect from renal or endocrine disease, have undergone urethral catheterization, or have a perineal urethrostomy. Dogs can develop a UTI without underlying anatomic, functional, or metabolic risk factors, depending on exposure to a virulent uropathogen
 3. Metabolic conditions predisposing for UTI: Diabetes mellitus, hyperthyroidism, hyperadrenocorticism; exogenous steroids and immunosuppressive medications also create increased risk
 4. Anatomic defects should be excluded: Ectopic ureters, loss of urethral tone due to sphincter mechanism incompetence, urachal diverticulum, urethral stricture, and excessive hooding of the vulva with overlying skin
 5. Functional defects in the emptying capacity of the bladder should be excluded. Urinary retention after voiding can make it impossible to permanently sterilize the urine
 B. Clinical signs: Various combinations of urinating in unusual locations in the house, hematuria, stranguria, pollakiuria, dysuria, excessive attention to the genitalia (licking); rarely urinary incontinence unless due to urge
 C. Diagnosis
 1. Urinalysis usually suggests UTI when there is pyuria and bacteriuria in urinary sediment. Hematuria and proteinuria are often present, but not specific for UTI. In the presence of urease bacterial UTI, persistent alkaline urine (pH >7) may be observed
 2. Quantitative urine culture is the gold standard to prove UTI exists. Large bacterial growth is expected from infected urine in dogs and cats. Bacterial growth is reported as colony-forming units (CFU)/mL (how many organisms would have grown from 1 mL of urine, extrapolated from a 0.01 or 0.001 mL sample)
 a. Cystocentesis samples avoid genital and distal urethral contamination and are ideal for documentation of UTI. Urine from the bladder should normally reveal no bacterial growth, but sometimes a small number of organisms do grow from skin contamination; by convention, for a UTI to exist, more than 1000 CFU/mL is required. Large quantitative growth more than 100,000 CFU/mL occurs in many dogs with UTI; most with UTI have more than 10,000 CFU/mL. UTI can exist in cystocentesis samples when growth is more than 1000 CFU, especially if antibacterial medications have been given recently
 b. Catheterized samples reveal more than 1000 CFU/mL in male dogs and cats in those with a true UTI. Contamination with urethral and genital flora can be very high (i.e., more than 1,000,000 CFU) from catheterized samples from female dogs, so this method can be misleading and is not recommended
 c. Voided samples are not recommended for culture as these are often positive for bacterial growth and can reveal very large growth of organisms in those that do not have a UTI
 D. Treatment
 1. Urinary antibacterial treatment should be based on susceptibility testing results
 2. First-line choices for urinary antimicrobials: Amoxicillin, potentiated sulfa (trimethoprim or ometoprim), and first-generation cephalosporins
 3. For more resistant organisms: Fluoroquinolones (enrofloxacin, marbofloxacin, difloxacin, orbifloxacin) and clavulanate-potentiated amoxicillins
 4. For highly resistant organisms: Fluoroquinolones, ticarcillin, piperacillin, aminoglycosides, imipenem, and meropenem
 5. Urinary antimicrobial treatment is usually prescribed for 2 to 3 weeks for uncomplicated UTI
 6. Treatment success: Based on sterile quantitative urine culture results 3 to 5 days after stopping urinary antimicrobial treatment and again in 1 and 3 months. Do not rely on resolution of clinical signs
 E. Recurrent UTI
 1. Recurrent UTI: Positive quantitative urine culture following a course of treatment in a patient with or without clinical signs
 2. Possibility for reinfection with a different organism than originally isolated (old infection was eradicated and a new one took place). Faulty host defenses against ascending bacterial organisms account for multiple new infections; routine short courses of antibacterials achieve sterile urine until the next infection ascends. Prophylactic treatment protocols may be necessary
 3. Infection may be from same organism as originally isolated and was never eradicated; organism is deeply seated in a location that is difficult for antibacterials to achieve eradication (polyps, extensive bladder wall changes from chronic cystitis, urachal diverticulum, pyelonephritis, prostatitis) or the organism is resistant to commonly prescribed urinary antimicrobial drugs. Treatment for 6 to 8 weeks may be curative; a different class of antimicrobial with greater tissue penetration may be required

II. Feline idiopathic cystitis (FIC): Nonobstructive
 A. Introduction
 1. Cats with signs of LUTD (hematuria, dysuria, pollakiuria, stranguria) frequently do not have

a readily identifiable cause. These clinical signs traditionally were referred to as feline urologic syndrome or feline lower urinary tract disease, but these terms have been abandoned in favor of referring to the specific diagnosis such as idiopathic or urolithiasis

2. Idiopathic cystitis: Most common condition associated with signs of irritative voiding in cats, followed by struvite and calcium oxalate urolithiasis, anatomic defects such as urethral stricture and urachal diverticulum
3. Bacterial UTI: Exceedingly uncommon as the cause for signs of LUTD in young cats that have not had a perineal urethrostomy or undergone urethral catheterization
4. Bladder or urethral neoplasia: Much less common in cats than dogs

B. Risk factors
 1. Male and female cats at equal risk. Male cats with FIC can progress to urethral obstruction (urethral plugs or spasm)
 2. Risk factors include neutering (but not time of neutering), obesity, amount of dry food consumed, and time spent indoors. Highly sensitive cats are at more risk for FIC than less sensitive cats

C. Physical examination: Thickened and or painful bladder; bladder is small or normal size

D. Pathophysiology
 1. A highly permeable bladder with activation of sensory nerve endings is important in initiation and maintenance of FIC; excessive stimulation of uroepithelial cells by catecholamines may be important. Decreased glycosaminoglycan (GAG) excretion is part of FIC pathophysiology; decreased GAG excretion could contribute to increased bladder permeability if there is a GAG layer on top of the uroepithelial cells. Access of the constituents of urine to the bladder wall following increased permeability activates the sensory neurons to bombard the brainstem with pain signals
 2. Excessive activation of neuradrenergic outflow from the brainstem is central to the pathophysiology of FIC in cats; may be secondary to activation from pain sensation in the brainstem or from activation of the brainstem from higher centers (as from stress recognized in the cerebral cortex). Excess adrenergic outflow can upregulate the inflammatory response within the bladder. The process is called *neurogenic inflammation*

E. Diagnosis
 1. More than 80% of cats with FIC resolve their clinical signs within 1 week of an acute episode; more than 50% of cats will have recurrence within 1 year. Outcome can be a one-time episode, occasional acute episodes, multiple acute episodes, or chronic smoldering episodes that never go completely away
 2. Diagnosis is mostly one of exclusion. Diagnostic evaluation is negative for urinary stones based on urinary tract imaging, quantitative urine culture is negative, and anatomic defects are absent based on imaging studies
 a. RBCs and protein in the urine are frequently positive; this can wax and wane so not always present despite the presence of disease
 b. A mild increase in WBC in the urinary sediment can be observed, but often the WBC count is normal and is dwarfed by the numbers of RBCs. Typical urinary sediment is referred to as *hemorrhagic inflammation,* emphasizing the paucity of the WBC response
 c. Sometimes transitional epithelial cells are seen in excess during FIC because of the exfoliation of cells from the bladder during the inflammatory response
 d. Urine should be concentrated to at least USG of 1.035. Many cats with FIC have USG in excess of 1.050 and some are above 1.070
 e. Bladder imaging with contrast cystography or ultrasonography can reveal focal or diffuse thickening of the bladder wall in chronic cases. Normal bladder imaging does not exclude the diagnosis of FIC
 f. Cystoscopy often reveals signs of cystitis such as increased vascularity, vascular tortuousity, and edema of the bladder wall; "glomerulations" (submucosal petecchiation) may be visible

F. Treatment includes special attention to reduction of stress in the environment, dietary change, water dynamics, litter box hygiene, and pain relief
 1. Antibiotics are useless in most cases because this is not a bacterial disease
 2. Glucocorticosteroids provide no known benefit
 3. NSAIDs have not been studied as to their utility
 4. Analgesia is given for 3 to 5 days. Oral buprenorphine or butorphanol is usual first choices. Opioids can be chosen for severe pain
 5. Increasing water intake appears to be useful in prevention of recurrences
 a. This is most readily accomplished by the feeding of canned foods if the cat can be successfully transitioned to these foods. Adding water to both canned and dry food can be attempted. The goal is to decrease the USG to less than 1.030 or at least less than it was initially
 b. Fresh water can be used to increase water intake. Many cats will consume more water when water bowls are filled to the top several times throughout the day. The use of distilled water has not been studied, but some cats may drink more water if their usual source of water is heavy with chlorine or minerals from the tap
 c. The goal of diluting the USG is that more dilute urine may be less noxious when it gains access to the bladder wall (see permeability pathophysiology above). Presumably, a larger urine volume will result in more frequent emptying of the bladder

6. There is no specific veterinary food that has been developed to specifically manage FIC; such products are usually marketed to include management of urinary stones that have an inherently different pathophysiology. Urinary acidification and magnesium restriction have no useful role in the treatment of FIC
7. Neither GAG replacement nor feline facial pheromones have been shown to be more effective than placebo in treatment of FIC in cats
8. Tricyclic reuptake inhibitors such as amitriptyline and clomipramine: Useful in the management of some cats with chronic FIC. Prozac (fluoxetine) has had a benefit for some cats. Not used to manage acute FIC; reserved for those with multiple recurrences or those with smoldering FIC unresponsive to more conservative treatments. There are many possible mechanisms for the benefits of these drugs including antiinflammatory and analgesic effects, and reduced activation of the adrenergic nervous system that can be helpful to reduce the inflammatory response
9. Environmental modification or enrichment: Single most powerful treatment for cats with FIC. Increasing the opportunities for exploration and for excitement while living indoors can be pivotal in helping some cats. Environmental modification and enrichment include excellent litter box management (one litter box for each cat plus one additional box, good cleaning habits), provision of vertical climbing spaces, enhanced interaction with people, good water management, increased access to the outdoors

III. Urolithiasis (bladder calculi)
A. Introduction.
1. Definition: Uroliths or calculi are concretions of minerals with a small portion of matrix proteins that form in the urinary tract. Uroliths form when urine is oversaturated with minerals in susceptible individuals. Supersaturation occurs when the concentration of calculogenic minerals is increased
2. Location: Urinary bladder is the most common site. Uroliths may be present without crystals, and crystals may be present without forming uroliths (Figure 28-1)

B. Risk factors
1. Urine pH and promoters or inhibitors of crystal formation: May affect the solubility of the calculogenic minerals
2. Metabolic disease such as urate-containing calculi in dalmatians and calcium-containing uroliths in animals with hypercalcemia
3. Additional risk factors for urolith formation: Breed, gender, age, and diet. Once initiation of urolith formation has occurred, the nidus must be retained within the urinary tract, and conditions must favor continued precipitation of minerals to promote growth of the urolith

C. Pathophysiology
1. Urethral obstruction occurs if stones are small enough to move out of the bladder but too big to move through the urethra
2. Calculi can cause irritation to the bladder mucosa, leading to inflammation and cystitis
3. Calculi can also serve as substrate for bacteria, leading to difficulty resolving bacterial UTI

D. History and clinical signs
1. Clinical signs: Hematuria, stranguria, dysuria, and pollakiuria; signs are similar regardless of the type of urolith present. Some exhibit no clinical signs. Bacterial infections worsen the signs
2. Some uroliths may be passed in the urine. If obstruction occurs, there will be difficulty voiding

E. Diagnosis
1. Uroliths are considered in animals that have predisposing factors (e.g., systemic disease, history of stone formation)
2. Physical examination: Stones may be palpable in the bladder or the urethra
3. Urinalysis may reveal hematuria, bacteriuria, and changes in pH typical of the type of stone present
4. Crystalluria may be present without stones, and stones may be present without crystalluria. Therefore, crystalluria is not helpful in the diagnosis of calculi
5. Urine culture is indicated to identify any UTI (primary or secondary)
6. Complete blood cell count (CBC)/biochemistry: Usually normal; hypercalcemia in 4% of dogs and 35% of cats with calcium oxalate uroliths
7. Radiographs: Radiopaque uroliths include struvite, calcium oxalate, and calcium phosphate. Stones must be 3 mm or greater in diameter to be seen. Radiograph the entire urethra to look for calculi. Double-contrast radiography may be needed to demonstrate urate and cysteine uroliths, which are radiolucent
8. Ultrasonography is helpful in identifying calculi in the bladder and proximal urethra regardless of their radiodensity but cannot examine the distal urethra
9. All retrieved uroliths should be submitted for quantitative analysis

F. Differential diagnosis
1. Any form of cystitis
2. Bladder neoplasia

G. Treatment (general)
1. Remove surgically if there is repeated urethral obstruction or the owners do not wish to attempt medical dissolution
2. If the urolith is smaller than the diameter of the urethra, it may be retrieved using voiding urohydropropulsion or catheter-assisted retrieval technique

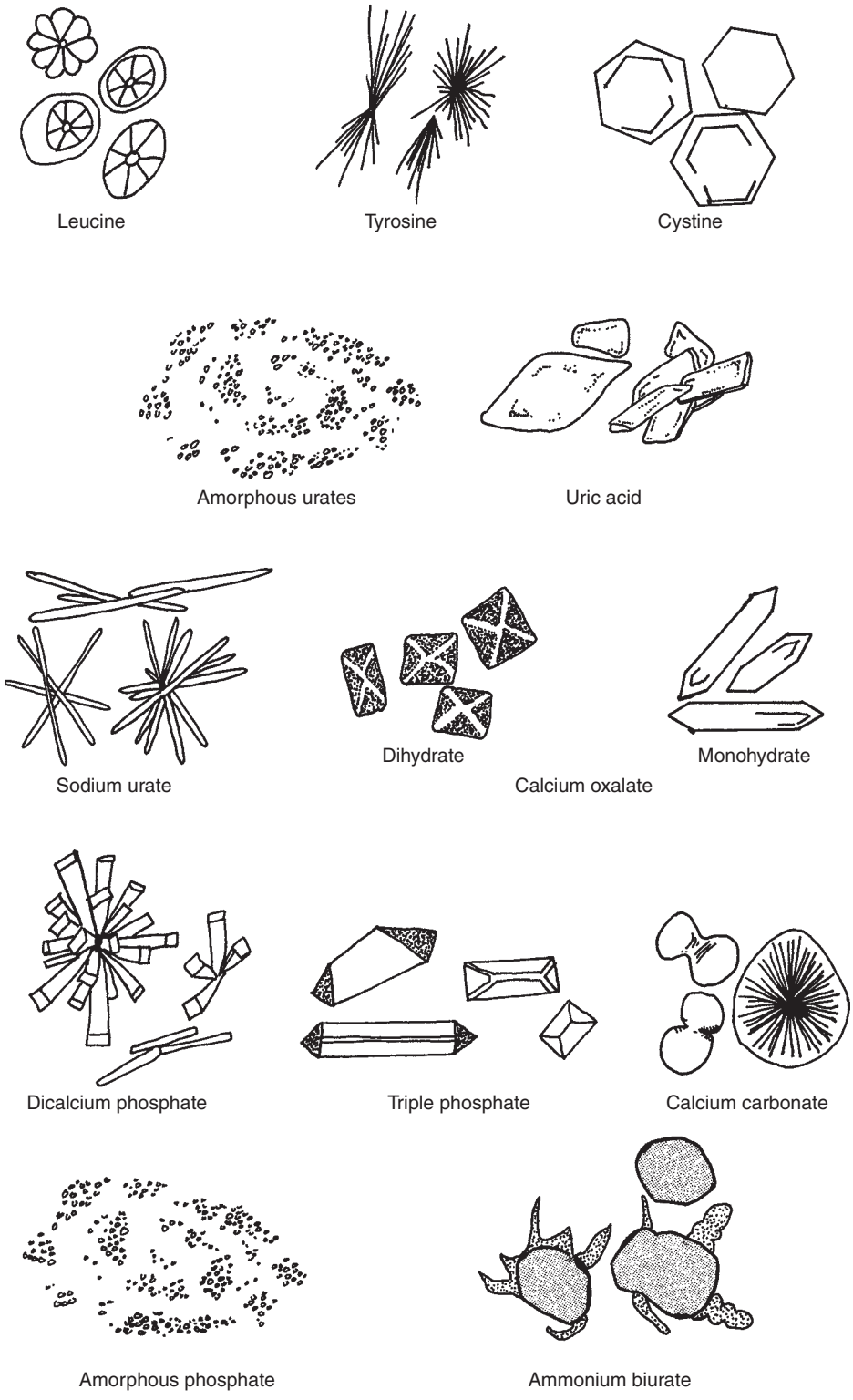


Figure 28-1 Casts commonly found in urine sediment smears. (From Cowell RL et al. *Diagnostic Cytology and Hematology of the Dog and Cat,* 3rd ed. St Louis, 2007, Mosby.)

3. If using medical dissolution, continue therapy for 1 month after radiographic resolution of the uroliths. If there has been no improvement after 4 to 6 weeks of therapy, surgery should be considered
4. After initial therapy, prevention and follow-up evaluations should occur

H. Prevention of uroliths (general)
 1. Most uroliths can recur; therefore, preventive measures should be instituted
 2. Increase water intake: Feed canned food or add water to dry food. Provide additional water bowls, good water bowl hygiene, and different sources of water

I. Types of uroliths
1. Struvite uroliths
a. Struvite (triple phosphate) is the most common urolith in dogs
b. In both dogs and cats, struvite uroliths are more likely to form in alkaline and infected urine
c. A urine culture positive for urease-producing organism (usually *Staphylococcus* spp. or *Proteus* spp., occasionally *Streptococcus* spp., *Klebsiella* spp., or *Ureaplasma* spp.) is necessary for infection-induced struvite uroliths to develop. In cats, 95% of struvite uroliths are sterile
d. Increased risk: Miniature schnauzer, shih-tzu, bichon frise, Lhasa apso, miniature poodle, cocker spaniels (sterile type), ragdoll, foreign shorthair, domestic shorthair, Oriental shorthair, Chartreux, and Himalayan. Decreased risk: Rex, Burmese, Abyssinian, Russian blue, Siamese, and Birman cats
e. Risk factors: Diets high in protein, magnesium, and phosphorus, with increased urine excretion of magnesium and phosphorous
f. Treatment
(1) Infection-induced: Use appropriate antimicrobial therapy based on culture and sensitivity and a diet designed for struvite dissolution (protein and magnesium restricted; acidic urine). Average time for dissolution of canine uroliths is 12 weeks
(2) Sterile: Same as infection-induced struvite uroliths except that antimicrobial therapy is not necessary. Average dissolution time for dogs and cats is 4 to 6 weeks
g. Prevention of infection-induced uroliths: Prevent recurrence of infection, treat causes of recurrent UTI (hyperadrenocorticism, diabetes mellitus); correct structural abnormalities (perivulvar dermatitis, recessed vulva) that can predispose to UTI, use low-dose antibiotic therapy as prophylaxis if necessary. Increase water intake; encourage frequent voiding
h. Prevention of sterile uroliths: Modify diet; acidify diet, but avoid excess acidification of urine (pH less than 6.0). Magnesium restriction may be beneficial
2. Calcium oxalate uroliths
a. Calcium oxalate crystalluria: More likely to occur in acidic urine because of systemic acid-base effects and not the effects of urine pH favoring precipitation
b. Risk factors: Hypercalcemia, administration of calciuretic substances (e.g., saline diuresis, furosemide, glucocorticoids), hyperadrenocorticism
c. Increased risk: Male dogs; miniature schnauzer, shih-tzu, bichon frise, Lhasa apso, Yorkshire terrier, miniature poodle, Persian, Himalayan, ragdoll, British shorthair, foreign shorthair, exotic shorthair, Havana brown, and Scottish fold. Birman, Abyssinian, and Siamese cats are at decreased risk
d. Treatment: Remove surgically or by urohydropropulsion
e. Recurrence is common. Evaluate for hypercalcemia, metabolic acidosis, hyperadrenocorticism, or UTI. Avoid glucocorticoids; increase water intake. Avoid acidifying diets, diets restricted in phosphorus or magnesium; avoid vitamins C and D and calcium supplements. Fasting urine pH should be maintained between 6.5 and 7.0
3. Ammonium urate uroliths
a. Cause: Increased urates in urine, usually from increased dietary intake of purines (precursors of uric acid); more likely in acidic urine. Occurs secondary to impaired ability to convert uric acid to allantoin (especially in dalmatians, English Bulldogs); formation is also associated with portosystemic shunts or hepatic microvascular dysplasia
b. Treatment with portosystemic shunt: Surgical removal. Feed low protein, alkalinizing diet if shunt is not correctable. Canned formulations are more effective than dry
c. Treatment for other causes: Feed low-protein diet without fish or glandular organs, maintain urine pH at 7.0 to 7.5, increase water intake; treat with allopurinol if diet alone is not effective. Average dissolution time is 4 weeks, and medical dissolution is successful in about 50% of cases. Animals treated with allopurinol are at increased risk of developing xanthine uroliths (Figure 28-2)
4. Calcium phosphate uroliths
a. Pure calcium phosphate (hydroxyapatite) uroliths occur infrequently in dogs and cats. Calcium phosphate is more commonly found as a component of other stones (such as struvite uroliths)
b. Increased risk: Miniature schnauzer, bichon frise, shih-tzu and Yorkshire terrier
c. Alkaline urine causes increased precipitation; hyperparathyroidism is associated with calcium phosphate urolithiasis
d. Calcium phosphate uroliths should be surgically removed
5. Cystine uroliths
a. Result of a congenital metabolic defect. Stone formation is uncommon but is more common in acidic urine
b. Increased risk: Mastiff, Newfoundland, English bulldog, dachshund, Tibetan spaniel, basset hound, and Siamese cats. Males are more likely to develop cystine uroliths than females
c. Medical treatment includes increasing water intake, maintaining a urine pH of 7.0 to 7.5

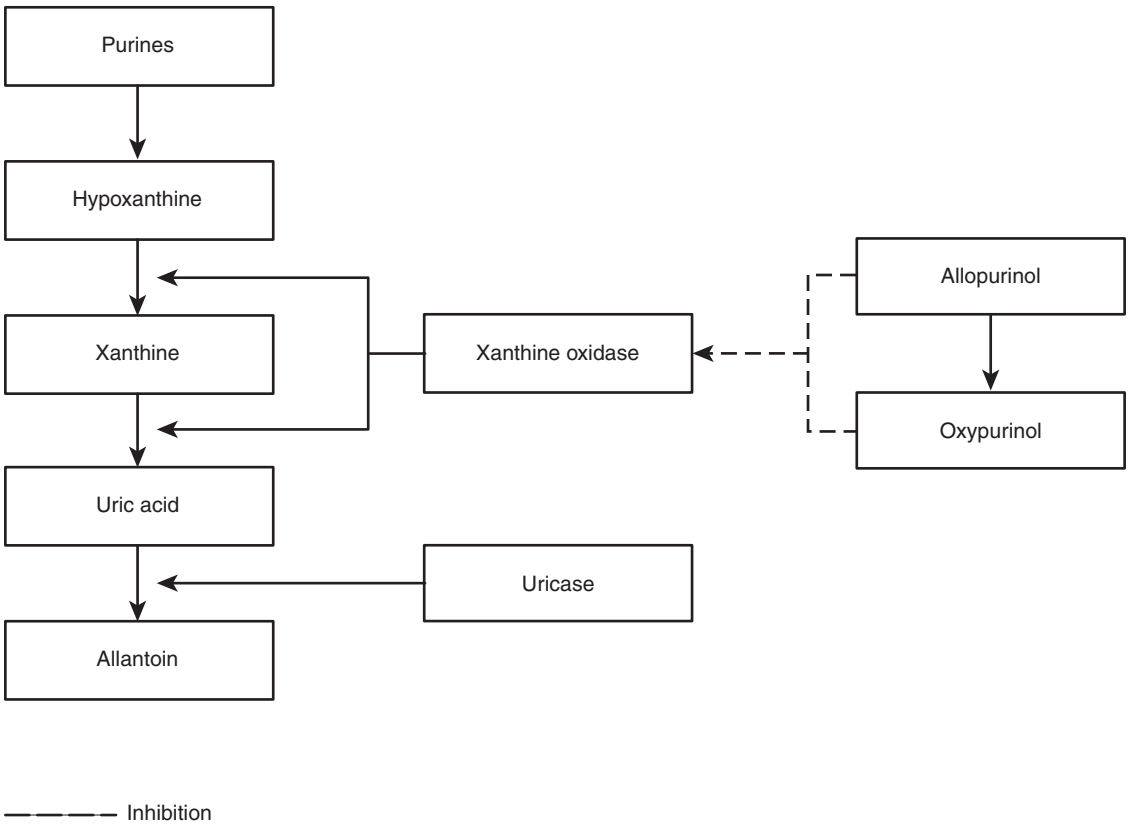


Figure 28-2 Metabolic pathway of purine degradation to allantoin showing site of action of allopurinol. (From Ettinger SJ, Feldman EC, editors. *Textbook of Veterinary Internal Medicine,* 6th ed. St Louis, 2005, Saunders.)

with diet or potassium citrate, avoiding high-protein diets, and using a thiol-containing drug such as n-(2-mercaptopropionyl)-glycine (2-MPG) or penicillamine. Regenerative anemia, myopathy, and aggression have been noted with the use of 2-MPG. Time for stone dissolution is 4 to 12 weeks

d. Any secondary UTI should be treated, and recurrence is common

6. Xanthine uroliths
 a. Primary xanthine urolithiasis: Uncommon; due to an inborn error of metabolism (xanthine oxidase deficiency)
 b. Occur secondary to allopurinol administration, especially if on a high-purine diet
 c. Increased risk: Cavalier King Charles spaniels and dachshunds. More frequent in breeds most likely to be treated with allopurinol (dalmatians)
 d. Treatment: Low-purine diet; diets are low in protein with mostly plant-based protein sources
7. Silica uroliths
 a. Silica uroliths occur rarely in dogs and cats
 b. Cause: Diets high in corn gluten or soybean hulls
 c. German Shepherd dogs and Old English sheepdogs have an increased incidence. Males are affected more frequently than females. There is no reported feline predisposition
 d. Treatment: Surgery; no medical therapy

IV. Urinary incontinence
 A. Introduction
 1. *Urinary incontinence* is defined as the involuntary passage of urine; differentiate from polyuria and polydipsia and increased voiding from lower UTI
 2. More common in dogs than cats. In cats, urge incontinence secondary to lower urinary tract inflammation is most common
 3. Causes: Anatomic and functional defects of the bladder and urethra; bladder pressure is greater than urethral pressure (low urethral tone is most common). Differentials include the following:
 a. Neurogenic: Lower or upper motor neuron disorders, an inability to voluntarily initiate a detrussor contraction, associated with urine retention in the bladder
 b. Anatomic: Ectopic ureter, patent urachus, vesicourethral fistula, urethral-vaginal fistula, urethral-rectal fistula, pelvic bladder (some have no clinical signs)
 c. Functional: Urge, primary urethral sphincter mechanism incompetence, overactive bladder (detrussor hyperreflexia), detrussor-urethral-dyssynergia (DUD), paradoxical overflow (outflow obstruction), overflow associated with atonic bladder

B. Primary sphincter mechanism incompetence (PSMI)
 1. PSMI (idiopathic incontinence, hormone-responsive incontinence) is the most common and important acquired cause of incontinence in dogs
 2. Cause
 a. Typically in spayed female dogs; in some breeds incontinence may precede ovariohysterectomy (OHE)
 b. Decreases in maximal urethral closure pressure and functional urethral length predictably occur during the first 12 to 18 months after spaying, with a deterioration of urethral closure function; the decline continues with age. About 20% develop PSMI a mean of 2.9 years after OHE. Increased risk: Dogs weighing more than 20 kg (31%); boxers (Europe), Dobermans, and giant schnauzers (United States). Incontinence is about half as frequent in bitches that undergo OHE before their first heat, but episodes of incontinence are worse
 3. Diagnosis
 a. Diagnosis is by exclusion in most cases
 b. Confirmation with urethral pressure studies: Low maximal urethral closure pressure and decreased functional profile length
 c. Typical cases of PSMI have episodes of incontinence while resting or recumbent, without signs of urgency at other times
 d. UTI is usually absent; some have ascending infection
 e. Should be able to concentrate urine
 f. Urinary tract imaging: Usually normal; may see pelvic positioning of bladder.
 4. Treatment
 a. Phenylpropanolamine (PPA): PPA orally two to three times daily effectively controls incontinence in about 74% to 92% of dogs by stimulating α-adrenoreceptors in the urethra and increasing urethral tone. May lose effectiveness over time; side effects include restlessness and mild behavioral changes (rare). Contraindicated in hypertension, cardiac disease, or renal disease
 b. Estrogens: Increases the sensitivity of α-adrenoreceptors in the urethra and increases urethral tone; effective in 65% to 83%. Diethylstilbestrol is used at the lowest dose that will maintain continence. Adverse effect: Bone marrow toxicity but safe at low doses. *Do not use estradiol cypionate (ECP)!*
 c. Treat with gonadotropin-releasing hormone analogues (leuprolide); results in complete continence in more than half of those that failed traditional medical therapy; most of the remaining dogs were improved but not completely continent
 d. Urethral bulking agents: Periurethral submucosal injections are administered through an operating cystoscope. Also used in dogs that cannot tolerate α-adrenergic drugs or estrogens, and some dogs with congenital urinary incontinence due to sphincter mechanism incompetence. Collagen is implanted in the submucosal layer of the proximal urethra; success rate 68%, lasting about 17 months
 e. Colposuspension is a surgical option. Urethral pressure is increased as the uterine remnant is stretched cranially and sutured to the prepubic tendon. This is an invasive procedure and has largely been replaced by urethral bulking procedures

C. Ureteral ectopia
 1. Introduction
 a. Ectopic ureters (EUs) are the most common congenital cause for urinary incontinence in female dogs. Much higher incidence in females. Males may not show signs of incontinence
 b. Breeds: Most common in golden retrievers, Labrador retrievers, Siberian husky, soft-coated wheaten terrier, poodles, and Newfoundlands
 2. Clinical signs
 a. The degree of urinary incontinence is variable
 b. Dogs with EU typically demonstrate normal voiding behavior in addition to constant or intermittent leakage of urine; up to 40% have intermittent incontinence
 c. The history of urinary incontinence usually can be traced to the time of weaning and is often mistaken as a behavioral problem associated with housebreaking
 d. Diagnosis of EU occurs most often by 7 months of age, although many can be diagnosed earlier
 e. UTI is encountered with EU in about two thirds of the cases
 f. Decreased urethral pressure is associated with EU in some dogs and may influence the prognosis for continence after surgical correction
 g. Hydroureter occurs in some dogs with intramural ectopic ureter
 3. Diagnosis
 a. Intravenous pyelography (IVP) can confirm the presence of ectopic ureter and is enhanced when performed using computed tomography (CT) or fluoroscopy. IVP is typically done in private practice
 b. Positive contrast vaginography or ultrasound can also be used
 c. Urethrocystoscopy is the method of choice to confirm EU
 d. Helical CT is superior to cystoscopy in males
 4. Location
 a. Most have bilateral EU (more han 90%)
 b. Nearly half of the ectopic ureteral openings are found in the distal urethra, with other openings in abnormal locations of the trigone, vesicourethral junction, proximal urethra, midurethra (rarely in the vestibule). Most are intramural

5. Treatment
 a. Surgical correction is based on location of the ectopic ureter and associated pathology
 b. Ureteral reimplantation**:** Reimplantation of the distal segment of the ureter into the bladder may restore continence
 c. Neoureterostomy and urethral/trigonal reconstruction: Intramural ectopic ureters that attach to the bladder in a normal anatomic position and fail to terminate and open into the bladder lumen at the tip of the trigone should be considered for neoureterostomy
 d. Nephroureterectomy: Removal of a nonfunctional or poorly functioning kidney and associated ureter as a salvage procedure (if contralateral kidney is normal). Severe dilation of the ureter and renal pelvis may be an indication for removal
 e. Complications: Persistent urinary incontinence in over half of patients after surgery. α-Adrenergic drugs (phenylpropanolamine, ephedrine sulfate) may help

D. Detrussor-urethral dyssynergia (DUD)
1. Urethra fails to relax while the detrussor is contracting; usually due to excessive smooth muscle tone but excessive somatic tone can also occur. Often idiopathic
2. DUD occurs in large male dogs (weighing more than 25 kg); occurs in castrated and intact males
3. A urine stream is initiated but is small and weak with premature termination; spasms may be observed. Urine dribbling may occur; distinguish from partial obstruction
4. Treatment: Decrease sympathetic tone with α-adrenergic blocking agents (phenoxybenzamine, prazosin, terazosin). A third of dogs respond with immediate and complete continence. Diazepam, antibiotics, and bethanecol may help. Skeletal muscle relaxation may be provided with diazepam or dantrolene

E. Patent urachus
1. If the urachus fails to close by birth, urine leaks from near the umbilicus
2. Diagnosis: Physical examination, imaging
3. Surgically remove; prognosis is excellent for continence

V. Urethral obstruction

A. Causes
1. Structural urethral obstruction is caused by anything that physically blocks the urethral lumen or compresses the urethral lumen from outside the urethra. Examples include intraluminal lesions (urethral calculi, neoplasia, mucous and crystal plugs, blood clots, strictures), and, less commonly, compression from external trauma to the pelvis area or lymphadenopathy
2. Functional urethral obstruction can be secondary to neurologic suprasacral spinal lesions, termed *reflex dyssynergia,* may be idiopathic, or secondary to pain and inflammation in the area (swelling and compression)

B. Clinical signs
1. Partial obstruction: Stranguria, pollakiuria, dysuria, hematuria, inappropriate urinations, and urine dribbling
2. Complete urethral obstruction: Frequent attempts to urinate with no production of urine. A small amount of urine may pass as a result of paradoxical incontinence. Uremia develops within a few days
3. Functional urethral obstruction results in normal initiation of voiding, followed by a decrease in urine flow with typical signs of partial urinary obstruction

C. Physical examination
1. The urinary bladder is distended, turgid, and painful. By definition, there is urethral obstruction if the bladder is full at a time of urinary urgency
2. It is usually not possible to express the bladder; do not apply great pressure on an already enlarged bladder
3. Rectal palpation and inspection of the tip of the penis may disclose a cause for the obstruction

D. Diagnosis
1. Hyperkalemia, metabolic acidosis, and azotemia; severity is dependent on duration of obstruction
2. Urinalysis: Hematuria, proteinuria, pyuria, and bacteriuria, depending on the underlying cause of the obstruction
3. Electrocardiogram: Cardiac arrhythmias resulting from hyperkalemia and metabolic acidosis
4. Radiography, contrast radiography (urethrogram, cystogram), or ultrasonography is useful to define the location and extent of the obstruction

E. Treatment
1. Place indwelling IV catheter for crisis management
2. Give potassium-free IV fluids (0.9% NaCl) to correct dehydration and replace urinary losses during postobstructive diuresis
3. With cardiac arrhythmias, assume hyperkalemia and metabolic acidosis. Dilution with IV fluids, IV dextrose (alone or in combination with insulin), calcium salts, and sodium bicarbonate infusions can be given
4. Decompress the bladder by cystocentesis before passing a urinary catheter. This takes pressure off the bladder and allows renal function to resume. Give adequate pain relief, sedation, and anesthesia to pass catheter without trauma
5. May be able to pass a urinary catheter around a urethral stone; if so, drain bladder and then use retropulsion to push stone back into the bladder. May be able to use retropulsion even if urinary catheter will not pass the stone
6. Maintain an indwelling urinary catheter until azotemia and postobstructive diuresis have resolved and urethral swelling has diminished

7. Urethrospasmomytic therapy with acepromazine and analgesics (buprenorphine) may facilitate a more patent urethra
8. Cystotomy for removal of stones retropulsed into the bladder

F. Postobstructive diuresis occurs following the relief of complete urethral obstruction
1. The magnitude of urine output usually parallels the degree of azotemia and spontaneously decreases as the azotemia decreases
2. Monitor urine output; with large urine output, potassium supplementation to IV fluids is needed to prevent hypokalemia

VI. Uroabdomen
A. Causes
1. Urine can enter the peritoneal cavity from tears in the bladder, urethra, or kidneys. Urine can enter the retroperitoneal space from the kidney and ureter
2. Bladder tears are most common, most following blunt trauma
3. Penetrating wounds occasionally are the cause for urine leakage
4. Tears can occur during overzealous expression of the bladder, passage of a urinary catheter, cystocentesis, abdominocentesis, surgical injury, breakdown of cystotomy closure, overdistension during contrast radiography and cystoscopy, and secondary to prolonged urethral obstruction. Transient leakage of sterile urine into the abdomen following cystocentesis is usually self-limiting and resolves quickly on its own

B. Clinical signs
1. Hematuria, dysuria, and stranguria
2. There may be no urine output; in others, some urine is voided and some accumulates in the abdomen
3. Systemic signs progressively develop over time
4. Progressive abdominal enlargement after administration of IV fluids

C. Physical examination
1. Abdominal or inguinal bruising or a penetrating wound may be observed
2. Pain during abdominal or rectal palpation
3. The presence of pelvic fracture increases the risk of bladder rupture
4. The urinary bladder may not be palpable or small if there is a bladder tear

D. Diagnosis
1. If there is a urethral tear, it might not be possible to pass a urinary catheter. With a bladder tear, the catheter may retrieve urine or urine plus fluid from the abdominal cavity
2. Urinalysis results vary depending on the duration of the tear. Early after a tear, urine is diluted in the peritoneal cavity. Urinalysis may show hematuria, proteinuria, and pyuria from trauma or chemical peritonitis
3. Serum biochemistry
 a. Creatine kinase, alanine aminotransferase, and aspartate aminotransferase may increase from trauma
 b. Early on, BUN, creatinine, and phosphorus are normal, but they increase as uroabdomen develops (postrenal azotemia). Azotemia develops by 24 hours postrupture; it may occur sooner if there is shock or dehydration (prerenal factors)
 c. BUN and potassium elevate earlier than do phosphorus and creatinine
 d. Sodium and chlorine decrease, and potassium increases as urine in the abdomen equilibrates with extracellular fluid
4. Survey abdominal radiographs in urinary tract rupture: "Ground-glass" appearance with loss of abdominal detail
 a. Use positive contrast cystography to document urine leakage from the bladder
 b. Rupture of upper urinary tract: Loss of retroperitoneal detail, failure to observe the kidneys, and streaking of the retroperitoneal space
 c. IVP is needed to document the site of urine leakage from the kidney or ureter
5. Analysis of abdominal fluid: If urine, BUN, and creatinine in the fluid should be higher than in serum

E. Treatment
1. If a bladder tear is small, place indwelling urinary catheter for a few days. With larger tears, surgical closure is needed
2. Rupture of the urethra usually requires primary surgical closure. Rupture of the kidney often requires nephrectomy
3. Ureteral rupture can sometimes be managed by reimplantation of the ureter into the bladder; ureteral rupture can be surgically closed, but stricture is common
4. Short-term peritoneal dialysis or peritoneal drainage may be needed if urine flow cannot be established adequately with urethral catheterization

VII. Urinary bladder neoplasia
A. Introduction
1. Most frequently identified urinary tract tumor in dogs, accounting for 1% of all canine neoplasms. They tend to occur in older animals. Rare in cats
2. Transitional cell carcinoma (TCC) is most common in dogs. Lymphoma, fibroma, rhabdomyosarcoma, papilloma, squamous cell carcinoma, and adenocarcinoma occasionally occur. Rhabdomyosarcomas are rare but are seen in dogs younger than 2 years of age

B. Transitional cell carcinoma (TCC)
1. TCC is more frequent in female than male dogs; more common in male cats
2. Malignant and highly invasive by time of diagnosis
3. Differential diagnoses: Cystitis (especially proliferative cystitis), tumors of vagina, prostate, or urethra

4. Risk factors
 a. Breeds: Scottish terriers (nearly 18 times the risk compared with mongrel dogs), Shetland sheepdogs, collies, airedales, and beagles. German shepherd dogs are at reduced risk
 b. Exposure to herbicide lawn treatment or cyclophosphamide, flea or tick dips, overweight or obese, living near marshes sprayed for mosquito control
 c. Reduced risk if consuming green leafy vegetables at least three times weekly
5. Location: In dogs, about two thirds of TCCs occur in the trigone; about 30% of males have prostatic invasion. In cats, about 50% occur in the trigone. Masses can obstruct outflow into urethra or obstruct both ureters

C. Clinical signs
1. Clinical signs: Hemorrhage, sterile cystitis, secondary UTI, and outflow obstruction (hematuria, pollakiuria, stranguria, dysuria). Systemic signs (and azotemia) if there is total obstruction. May see cancer cachexia, lameness, or bone pain from paraneoplastic hypertrophic osteopathy or bone metastasis
2. Many dogs with TCC have secondary bacterial UTI
3. Large bladder tumors may be detected by abdominal palpation. A rectal examination can reveal extension of a bladder mass into the urethra. Bladder is large with urethral obstruction; kidney is enlarged if the ureter is obstructed

D. Urinalysis
1. Urine sediment: Hematuria, pyuria, neoplastic cells (often in clumps)
2. Cystocentesis is not recommended (can seed the abdomen and skin with neoplastic cells). Use catheterization or a voided sample

E. Diagnosis
1. Imaging: Enlarged kidneys or bladder with obstruction; sublumbar lymphadenopathy from metastasis, metastasis may be evident. Contrast cystography or ultrasound may show mucosal irregularity, thickening of the bladder wall, and filling defects
2. Cystoscopy is more sensitive than other imaging modalities in diagnosing and staging a mass and determining the extent of bladder involvement
3. Definitive diagnosis requires biopsy with histologic confirmation
4. Bladder tumor antigen test: V-BTA Test (Polymedco) is a urine test to screen for the presence of bladder tumor antigen in dogs. Useful to rule out neoplasia if test is negative

F. Treatment
1. Surgical excision using partial cystectomy is the treatment of choice. Surgical excision is rarely complete
2. TCCs do not respond well to chemotherapy. Lymphoma does respond to chemotherapy. Laser ablation can be combined with chemotherapy
3. Piroxicam (dosage for dogs is 0.3 mg/kg orally every 48 hours; undetermined dosage for cats) is recommended in all cases both for its analgesic and anti-tumor properties. Side effects include anorexia, vomiting, diarrhea, and GI ulceration
4. Tube cystotomy can be performed if urinary obstruction is present
5. Treat secondary UTI, and monitor for development

G. Long-term prognosis is poor

VIII. Urethral diseases

A. Clinical signs: Lower urinary tract urgency from inflammation and obstruction. Diagnosis by examination, urinalysis, imaging (urethrography). Ultrasound is not very useful except to evaluate prostate

B. Congenital urethral disease
1. Ectopic ureters terminating in the urethra is most common
2. Urethral hypospadia: Urethra opens on ventral penis or prepuce; from incomplete fusion of the urethral groove. Urinary scalding, recurrent UTI, and pyoderma may result

C. Urethral obstruction
1. The most common urethral disorder
2. Urolithiasis is most common in dogs; urethral plugs and idiopathic causes are common in cats. Neoplasia of the urethra or prostate or extraluminal tumors or swelling can cause obstruction
3. Clinical signs include urinary urgency; systemic signs if obstruction is long-standing

D. Urethritis
1. Proliferative urethritis (formerly called granulomatous urethritis)
 a. Secondary to chronic UTI; possibly immune-mediated. Occurs in middle-aged to older female dogs
 b. Urethra feels abnormally thickened on rectal palpation
 c. Cylindrical masses are present within the urethral lumen with nodular or finger-like projections. Biopsy is required
 d. Treat active UTI and then provide prednisone and azathioprine in a tapering regimen
2. Bacterial urethritis
 a. Usually with infection in more proximal locations of the urinary tract
 b. Treated the same as for bladder UTI
3. Sterile urethritis
 a. A condition of cats; affects males more often than females
 b. Treatment as for idiopathic cystitis, although antispasmodics may be added (e.g., acepromazine and analgesics such as buprenorphine)

E. Urethral trauma (blunt or penetrating) can include bruising, swelling, local urine accumulation, laceration, and avulsion

F. Urethral stricture
1. Causes: External trauma, internal urethral trauma (indwelling urinary catheter), urethritis, and following urethral surgery

2. Orphan pups and kittens may suck on the external genitalia of others in the litter, resulting in urethral trauma and stricture

G. Urethral prolapse
 1. An acquired condition of male dogs
 2. Sexual excitement is a predisposing cause
 3. Young male bulldogs, Boston terriers, and shar-peis are predisposed
 4. Treat with surgical resection

H. Urethral neoplasia
 1. TCC or squamous cell carcinoma most common. Leiomyosarcoma, leiomyoma, rhabdomyosarcoma, adenocarcinoma, hemangiosarcoma, and undifferentiated sarcoma also occur
 2. Most common in older female dogs. In males prostatic adenocarcinoma and TCC may extend into the urethra
 3. As in bladder tumors, some urethral tumors respond to piroxicam

Supplemental Reading

Bartges JW, Osborne CA, Lulich JP et al. Canine urate urolithiasis: etiopathogenesis, diagnosis, and management. *Vet Clin North Am* 29:161-191, 1999.

Bartges JW, Kirk C, Lane IF. Update: management of calcium oxalate uroliths in dogs and cats. *Vet Clin North Am Small Anim Pract* 34:969-987, 2004.

Chew DJ, DiBartola SP. *Handbook of Canine and Feline Urinalysis.* St Louis, 1998, Ralston Purina Company.

Chew DJ, Gieg J. Fluid therapy during intrinsic renal failure. In DiBartola SP, ed. *Fluid Therapy in Small Animal Practice.* St Louis, 2006, Saunders, pp. 518-539.

DiBartola SP. Applied renal physiology. In DiBartola SP, ed. *Fluid Therapy in Small Animal Practice.* St Louis, 2006, Saunders, pp. 26-46.

Gieg J, Chew DJ, McLoughlin MA. Diseases of the urinary bladder. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 895-914.

Grant D, Forrester SD. Diseases of the kidney and ureter. In Birchard SH, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 861-888.

Grauer GF. Early detection of renal damage and disease in dogs and cats. *Vet Clin North Am Small Anim Pract* 35(3):581-596, 2005.

Grauer GF. Canine glomerulonephritis: new thoughts on proteinuria and treatment. *J Small Anim Pract* 46:469-478, 2005.

Jacob F, Polzin DJ, Osborne CA et al. Clinical evaluation of dietary modification for treatment of spontaneous chronic renal failure in dogs. *JAVMA* 220:1163-1170, 2002.

Ling GV, Norris CR, Franti CE et al. Interrelations of organism prevalence, specimen collection method, and host age, sex, and breed among 8,354 canine UTIs (1969-1995). *J Vet Intern Med* 15:341-347, 2001.

Matthews HK. Diseases of the urethra. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 922-929.

SECTION III EQUINE

29 CHAPTER

Anesthesia

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GENERAL INFORMATION

I. Anesthesia in the horse presents several challenges
 A. The horse has a pronounced flight-or-fight response, meaning that induction and recovery can be violent and difficult. For this reason, adequate preanesthetic sedation is important in this species
 B. The horse possesses several anatomic characteristics that contribute to commonly encountered problems in gas exchange and recovery
 1. The horse is a large animal with relatively small, fragile limbs
 2. The long, sloping diaphragm and poorly lobulated lungs mean that much of the equine lung is vulnerable to compression by the abdominal contents when the horse is recumbent
 3. When anesthesia is induced and the horse becomes recumbent, marked abnormalities in ventilation-perfusion matching and intrapulmonary shunting occur

II. Most anesthesia is short in duration and occurs in the field
 A. Short and simple procedures using injectable anesthetics are usually well tolerated
 B. As the length and complexity of the procedure increase, the chance of anesthetic-related morbidity or mortality increases
 C. When inhalant anesthetics are used to maintain anesthesia, myocardial depression and hypotension are commonly encountered (Table 29-1)

ANESTHETIC AND SEDATIVE AGENTS

I. To produce standing restraint, or to calm and relax a horse before anesthesia, four different classes of compounds are used: The α_2 agonists, the phenothiazine tranquilizer, benzodiazepines, and mixed opioid agonists-antagonists. These compounds are frequently combined

II. α_2 Agonists
 A. Sedatives with analgesic properties
 B. Include xylazine, detomidine, medetomidine, romifidine
 1. Xylazine is approved for use in the horse, not for use in meat production
 2. Detomidine is approved for use in the horse, excluding breeding stock and meat production
 3. Romifidine is approved for use in the horse
 4. Detomidine and romifidine are more potent and longer lasting than xylazine
 C. Actions
 1. Produce stimulation of the presynaptic and postsynaptic α_2-adrenoreceptor, causing a decrease in release of catecholamines
 2. Profound muscle relaxation
 3. Potent visceral analgesics
 4. Produce peripheral vasoconstriction and increased blood pressure
 5. Associated decrease in heart rate with first- and second-degree atrioventricular (AV) block
 6. Decreased cardiac output, respiratory rate
 7. Diuresis
 D. Disadvantages
 1. Produce elevated blood glucose, decreased plasma insulin, decreased hematocrit
 2. Cause decreased intestinal motility, may reduce intestinal blood flow
 3. Will produce sweating, penile prolapse, congestion of nasal mucosa, relaxation of upper airway, occasional snoring
 4. Depresses thermoregulation in foals
 5. May make horses more irritable and likely to bite or kick even though they appear sedate
 E. Produce regional analgesia via epidural injection as well
 F. Lack of oxytocic effect on the pregnant uterus
 G. Onset of effect: 2 to 5 minutes after intravenous (IV) injection, 15 to 20 minutes after intramuscular (IM) injection
 H. Subtle effects of the drugs can persist for 24 hours
 I. Xylazine does not appear to lower the arrhythmogenic dose of epinephrine
 J. Can be combined with butorphanol or acepromazine or both to potentiate the sedative effects
 K. Detomidine is effective when given transmucosally but not if swallowed; onset is 40 minutes

Table 29-1 Normal Cardiopulmonary Values Under Anesthesia

Variable	Normal Value
Respiratory rate (beats/min)	5-12
Heart rate (beats/min)	25-50
Tidal volume (mL/kg)	10-20
Mean arterial blood pressure (mm Hg)	60-100
CVP (cm H_2O) Lateral	10-30
dorsal recumbency	5-10
End-tidal carbon dioxide tension (mm Hg)	50-70

L. Detomidine infusion provides excellent long-lasting standing sedation and can be used during surgery to reduce need for inhalant
M. α_2 Antagonist
1. Yohimbine approved for use in the dog only
2. Tolazoline approved for use in the horse, not for meat production
3. Atipamezole approved for use in the dog only
4. Competitive antagonists
5. May cause transient hypoxemia
6. Reverses the cardiovascular effects of all the α_2 agonists
7. Administration soon after ketamine or telazol may cause excitement, delirium, and muscle contractions and is not recommended

III. Phenothiazine tranquilizers
A. Include promazine, acetylpromazine
1. Approved for use in the horse, dog, and cat
2. Dopaminergic antagonist
B. Effects
1. Depresses alertness
2. Produces abolition of conditioned avoidance responses
3. Dose-dependent blockade of peripheral α_2-adrenoreceptor function
4. Produces potent peripheral vasodilation, decreased blood pressure, decreased central venous pressure, reduced hematocrit; may reduce cardiac output
5. Mild anticholinergic, antiemetic, antiarrhythmic effects
6. Depresses thermoregulation
7. Inhibits platelet function
8. Causes relaxation of the retractor penis muscle in stallions and geldings and reported to cause priapism occasionally. Be sure that the penis retracts back into the prepuce within a few hours of drug administration or intervention (hydrotherapy, benztropine, sling, support) is necessary
C. Effective after oral, IV, or IM administration
1. Increasing the dose usually does not increase sedation
2. Intracarotid injections may prove lethal
3. Show little effect in excited horses (effects can be overridden)
D. Contraindications
1. Neonates
2. Hypovolemic patients
3. Surgical colics
4. Anemic patients
5. Do not use in cases of organophosphate poisoning
E. Treat overdose with vasoconstrictor, fluid therapy, but not epinephrine
F. Onset of effect is 5 to 20 minutes following IV injection; similar following IM injection
G. Antagonist. None available

IV. Benzodiazepine tranquilizers
A. Extra-label use in the horse
B. Not used for routine standing restraint
C. Cause decreased anxiety, muscle relaxation
D. Potent antiseizure agents
E. Seldom used alone
F. Will produce mild sedation in foals
G. IV injection of large doses of diazepam alone in adult horses will cause stimulation, increased motor activity, then muscle relaxation, ataxia, possible recumbency
H. These drugs potentiate the duration and quality of anesthesia if administered with ketamine
I. Antagonist
1. Flumazenil (Romazicon)
2. Commercially available benzodiazepine antagonist
3. Extra-label use in the horse
4. Not very potent

V. Opioid agonists-antagonists
A. Butorphanol is the main opioid agonist-antagonist used in the horse
1. Butorphanol is considered a mild analgesic
2. Butorphanol is Food and Drug Administration (FDA) approved for use in the horse, not for meat production
B. Ceiling effect for analgesia
C. May produce some central nervous system excitement; combine with a sedative or tranquilizer
D. Potentiates the restraint when combined with sedative or tranquilizer
E. Morphine
1. Not FDA approved for use in the horse
2. Epidural morphine has been shown to produce effective analgesia in horses with hindlimb pain
F. Meperidine (Demerol)
1. Not FDA approved for use in the horse
2. Meperidine is a more potent analgesic with short duration of effect
G. Methadone
1. Similar to butorphanol in analgesic effect and durtation of effect
H. Side effects tend to be dose dependent
I. Antagonist
1. Naloxone is a potent opioid antagonist
2. Reverses all μ-receptor effects
3. Extra-label use in the horse

VI. Anticholinergics
A. Include atropine, glycopyrrolate
1. Neither atropine nor glycopyrrolate are specifically approved for horses
2. Not used routinely

B. Useful in treating or preventing α_2-agonist induced bradycardia and AV block, the oculocardiac reflex, and organophosphate poisoning
C. Causes reduced peristalsis and propulsive activity of the intestinal tract, which may cause colic, especially in recently fed horses
D. Colic is the most commonly encountered side effect that limits the use of atropine in the horse
E. Mydriasis may persist for 24 hours, so wait this interval before exposure to full sunlight
F. Remember that atropine ophthalmic ointment contains a lot of atropine that is readily taken up by the systemic circulation

INDUCTION AGENTS

I. Guiafenesin
A. Centrally acting internuncial neuron blocker
B. Produces mild sedation, muscle relaxation
C. Approved for use in the horse, not for meat production. Three-day withdrawal for meat
D. Mild decrease in arterial blood pressure
E. Integral component of "triple drip"
F. Can use 5% or 10% solutions in horses
1. 10% solution given IV in horses causes an adherent thrombus at the site of venepuncture
2. Use only 5% solution in cows to avoid intravascular hemolysis
G. Elimination is rapid
H. Mildly irritant if injected perivascularly
I. Crosses the placenta and can be found in foal serum
J. Lethal dose is three times the anesthetic dose
K. Extensor rigidity is a sign of toxicity

II. Thiobarbiturates
A. Include thiopental, thiamylal
B. Extra-label use in the horse
C. Classified as a hypnotic sedative
D. Irritant if injected perivascularly
1. If perivascular injection occurs, inject the area with a volume of saline at least three times that of the barbiturate injected
2. Administration through a catheter is recommended
E. Highly protein bound, can increase free (active) drug if co-administer phenylbutazone
F. Competes for protein-binding sites with phenylbutazone, so do not give both drugs IV at the same time because a relative overdose of the barbiturate will occur
G. Recovery begins with redistribution of the drug from the brain, ends in metabolism (hepatic) and excretion (renal)
H. Induction may be less controlled than with ketamine
I. Usually combined with guiafenesin
J. Contraindicated in neonates, hypovolemia, hemorrhagic shock, surgical colics, anemia, liver disease

III. Dissociative anesthetics (cyclohexamines)
A. Include ketamine and tiletamine (incorporated in Telazol)
1. Ketamine approved for use in cats and subhuman primates, extra-label use in horses
2. Telazol contains tiletamine and zolezapam; approved for use in cats and dogs, extra-label use in horses
B. Anesthesia lasts from 15 to 20 minutes following xylazine and ketamine. Anesthesia of 30 to 40 minutes' duration following Telazol
C. Generally smooth induction and recovery. Recovery can be rough if detomidine is used with Telazol
D. Apneustic respiratory pattern
E. Cardiovascular function well supported
F. Not irritant to tissues
G. Less cardiovascular depression than barbiturates
H. Eyes tend to stay open and staring; remember to lubricate them
I. Some horses (usually young pony colts) will not become anesthetized after administration of ketamine
J. Metabolized in the liver

IV. Propofol
A. Potent IV anesthetic
B. Not FDA approved for use in horses
1. Use in the foal and miniature horses most common
2. The cost of the agent tends to preclude its use in larger horses
C. Induces unconsciousness rapidly
D. Anesthesia lasts 5 to 10 minutes
E. Recovery is smooth, rapid
F. Can be used as an infusion to maintain anesthesia
G. Not irritant to tissues if inadvertent perivascular injection occurs

MAINTAINING ANESTHESIA

I. Inhalant anesthesia can be used following induction of anesthesia with IV agents
II. Likely to be used for procedures longer than 1 hour in duration
III. Orotracheal intubation uses extension of the head and a blind approach; ensures airway patency
IV. Cardiac output will be reduced by up to 50% of baseline values when the inhalant anesthetic agents are used
V. All the inhalants will be associated with mild hypercarbia and respiratory depression in the spontaneously ventilating horse
VI. The horse has poorly lobulated lungs and a long, sloping diaphragm
A. This makes a large portion of the lung vulnerable to compression by the bulky intestinal tract when the horse is in any position other than standing
B. Ventilation-perfusion mismatching is common in the horse under anesthesia. This occurs as a result of the unique pulmonary anatomy of the horse, which is vulnerable to compression by the bulky intestinal tract in recumbency
C. If the anesthetized horse is kept in the standing position, lung function remains normal

VII. Inhalant anesthetics
 A. Include halothane, isoflurane, sevoflurane
 1. Halothane not approved for use in food producing animals
 2. Isoflurane approved for use in the horse, not for meat production
 3. Sevoflurane not approved for use in the horse
 B. Nitrous oxide is not routinely used in the horse
 1. The potency of nitrous oxide is less in horses than in people, and factors such as arterial hypoxemia and diffusion hypoxia also limit its usefulness in the horse
 2. Nitrous oxide diffuses into closed spaces such as the intestinal tract, pneumothorax
 C. Isoflurane target species include horses, dogs, cats, ornamental birds, reptiles, small mammals excluding rabbits.
 D. Recovery
 1. Sevoflurane tends to produce rough recoveries in the horse unless xylazine is given in recovery
 2. Halothane recoveries are usually longer and often smoother than recovery from isoflurane or sevoflurane
 E. Halothane is more potent than isoflurane, which is more potent than sevoflurane
 F. Sevoflurane is the least soluble of the inhalant anesthetic agents used. Less solubility translates to faster inductions and recoveries (Table 29-2)

SUPPORTIVE THERAPY

I. Critical for ensuring optimal outcome in the horse
 A. Especially necessary if the procedure is complex and long
 B. Includes correct positioning, optimal padding of the surface the horse lies on
II. Oxygen supplementation is recommended for procedures that exceed 30 minutes
III. Endotracheal intubation is necessary if ventilation or gas anesthesia is to be provided
IV. Fluid administration helps support cardiac output
V. Fasting 4 to 6 hours is usually sufficient because gastric emptying is usually rapid
VI. Cardiovascular support includes use of an inotrope such as dobutamine or ephedrine

Table 29-2 Potency (MAC) and Blood Solubilities of Inhalation Anesthetics

Agent	MAC Volume %	Blood: Gas Solubility (37° C)
Halothane	0.88	2.3
Isoflurane	1.3	1.4
Enflurane	1.12	0.6
Sevoflurane	2.3	0.7
Desflurane	6.3	0.05

MAC, minimum alveolar concentration.

VII. Inefficient ventilation is best treated by mechanical ventilation

COMPLICATIONS

I. Despite the best care during anesthesia and recovery, horses will still die of anesthetic-related conditions. Some of these conditions will manifest during recovery. Others will occur during the anesthetic itself
II. Mortality
 A. Latest study indicates 0.9% anesthesia-related mortality in healthy horses
 B. Horses at greater risk
 1. Pregnant and foaling mares
 2. Older mares
 3. Draft breeds
 4. Large, heavily muscled and Impressive-bred horses
 5. Foals
 C. Fractured long bone is the most disastrous consequence during recovery; cannot be predicted or prevented
III. Thoracolumbar myelomalacia
 A. Occurs in young draft breeds
 B. In dorsal recumbency
 C. Cannot be predicted
 D. Irreversible
 E. Horse has no anal tone, hindlimb paralysis, sharp demarcation in panniculus reflex and cutaneous sensation
IV. Regurgitation and aspiration
 A. Uncommon
 B. Can occur if the stomach is greatly distended in a horse with colic
 C. Intubate the trachea as soon as possible after induction in at risk horses
V. Postanesthetic myopathy and neuropathy
 A. Most commonly affects the triceps muscle-radial nerve or the gluteal muscles-femoral nerves
 B. The facial nerve and peroneal nerve are also vulnerable to compression
 C. Factors contributing to this syndrome include lack of padding of the surface the horse lies on, incorrect positioning of the limbs (especially the dependent forelimb), and prolonged recumbency
 D. Arterial hypotension is also directly implicated in causing this condition
 E. Rarely following halothane administration, some horses may display a malignant hyperthermia–type syndrome, seen as tying-up of most of the major muscle groups, with pain and myoglobinuria seen in recovery or shortly thereafter
VI. Airway obstruction
 A. Edema of the nasal mucosa and displacement of the soft palate are commonly encountered during the postextubation period and in recovery
 B. Especially following prolonged recumbency and use of inhalant anesthetics
 C. May be severe enough to obstruct the airway completely
 D. Several cases of lethal postobstruction pulmonary edema have been reported in the horse

E. Placing a nasal or nasotracheal tube will reduce the work of breathing
F. Intranasal phenylephrine spray effectively reduces airway resistance.

VII. Hemorrhage
A. Severe hemorrhage is loss of more than 10% of the blood volume
B. Under anesthesia the horse will seldom manifest tachycardia during hemorrhage, even lethal hemorrhage
C. Signs observed during severe hemorrhage in the horse include pale or white mucous membranes, decreased arterial blood pressure
D. Concurrent decrease in the area under the arterial pressure waveform
E. Hematocrit does not change during acute hemorrhage
F. If vigorous fluid resuscitation occurs, hematocrit will decrease
G. Aim to resuscitate with IV crystalloid solution using three times the volume of blood lost

VIII. Hyperkalemic periodic paralysis
A. Impressive-bred horses
B. Attacks have been reported under anesthesia
C. Signs of an attack in an anesthetized horse include muscle fasciculations, sweating, characteristic changes on the electrocardiogram (ECG), preterminal bradycardia
D. If treated appropriately, these horses can make an uneventful recovery
E. Treatment must include IV dextrose; add sodium bicarbonate and/or calcium if severe episode or ECG changes are marked

IX. Apnea
A. Will follow iatrogenic hyperventilation (physiologic in this setting)
B. Usually indicates the horse is anesthetized too deeply
C. Requires immediate treatment
D. Can be one of the signs of cardiac arrest

X. Arterial hypotension
A. Causes
1. Commonly caused by the inhalant anesthetics secondary to myocardial depression
2. Will also be encountered in horses that are hypovolemic under inhalant anesthesia
B. Dobutamine is a potent inotrope (increases strength of cardiac contractility)
1. Dobutamine infusion is usually effective treatment of hypotension if blood volume is normal
2. Dobutamine is extremely potent, so must be administered by constant rate infusion
3. Dobutamine can induce severe arrhythmias and tachyarrhythmias, especially when large doses are administered
C. Calcium acts as a mild inotrope. Calcium chloride is three times as potent as calcium gluconate if solutions of equal concentration
D. Ephedrine is a mixed inotrope and vasoconstrictor that will also increase cardiac output and arterial blood pressure

XI. Bradycardia
A. Common, especially in the fit athlete
B. Exacerbated or caused by administration of xylazine, detomidine, romifidine
C. Second degree AV block also encountered
D. Usually physiologic
E. Will reduce cardiac output
F. Do not induce anesthesia if heart rate is less than 20 beats/min

XII. Draft breeds
A. Require less tranquilizer
B. At greater risk of postanesthetic myopathy and consequent inability to stand
1. To prevent this, minimize down time
2. Place on a well-padded surface
3. Maintain arterial blood pressure above 70 mm Hg to optimize muscle perfusion
C. Plan to assist recovery

XIII. Foals
A. Neonatal foals tend to be hypotensive, hypothermic, hypoglycemic, hypovolemic during anesthesia
B. Will sleep a long time after thiobarbiturates
C. Recover well from ketamine and diazepam
D. Inhalant induction also useful
E. Reduce the dose of α_2 agonists
F. Monitor blood glucose (hypoglycemia makes the foal hyporesponsive, weak). Anesthesia masks most of the signs of hypoglycemia
G. Monitor arterial blood pressure; normal values are lower in the foal than in adult horses
H. Ensure thermal homeostasis
I. Propofol is useful for inducing and maintaining anesthesia in healthy foals undergoing short procedures

FIELD TECHNIQUES

I. GKX
A. 5% guiafenesin, 0.1-0.2% ketamine, 0.05% xylazine
B. Maintenance of anesthesia; use of catheter is ideal
C. Useful in keeping horses anesthetized for up to 1 hour
D. Recovery will be rough, prolonged if more than 1 L of the mixture is used

II. Xylazine-ketamine
A. Provides smooth and controlled induction and recovery
B. Works best if the horse is well sedated before giving the ketamine
C. Can prolong duration of anesthesia by adding butorphanol or diazepam
D. Provides about 15 to 20 minutes of anesthesia time
E. Repeat dosing several times is acceptable
F. Cardiovascular function well preserved
G. Respiratory function well preserved
H. Probably the most commonly used anesthetic technique in the horse

III. Telazol
A. Provides smooth, controlled induction of anesthesia
B. Cardiovascular and respiratory function are well preserved

C. Will provide 30 to 40 minutes of anesthesia
D. Not irritant if injected perivascularly
E. Recovery will be rough with multiple attempts, especially if detomidine is given
F. Useful if inhalant anesthesia will follow the induction agent

SIGNS OF ACUTE PAIN IN THE HORSE

I. Signs of colic pain are easily recognized, including pawing, flank watching, kicking at belly
II. Signs of lameness cannot be masked and are easy to recognize
III. Visceral or somatic pain will produce behavior changes that are quite subtle
 A. Posture changes, head is lower, ears do not move
 B. Attention directed to the wall rather than to the door or passersby
 C. Eyes are dull, less interest in food or treats
 D. Horse interacts less with handler

COMMONLY USED ANALGESICS IN THE HORSE

I. Nonsteroidal antiinflammatory agents
 A. Includes phenylbutazone, flunixin, carprofen, meloxicam
 1. Phenylbutazone FDA approved for use in the horse, not for meat production
 2. Flunixin FDA approved for use in the horse, not for meat production
 3. Carprofen not FDA approved for use in the horse
 4. Meloxicam not FDA approved for use in the horse
 B. Toxicity
 1. Toxicity more profound in dehydrated patients
 2. Potentially hepatotoxic; may cause ulcerations in the dorsal colon, leading to abdominal pain and hypoproteineimia
 C. Concurrent administration of two antiinflammatories is called *stacking*. At present "stacking" of antiinflammatories is not more effective and is not recommended
II. Opioids
 A. Commonly used opioids include butorphanol, morphine, fentanyl
 B. Use is limited by the side effects induced by opioids in the horse
 C. Side effects tend to be dose related
 1. Side effects include mania, increased voluntary locomotor activity, colic, intestinal impaction
 2. No side effects observed following application of the fentanyl patch
 3. No side effects observed following epidural administration of morphine
 4. Mania can be treated by administration of acepromazine, xylaxine, detomidine
III. Lidocaine
 A. Local anesthetic producing nerve block for up to 4 hours
 B. Potent ventricular antiarrhythmic
 C. Given IV this drug produces analgesia, antitussive effects, putative intestinal prokinetic
 D. Few side effects observed following IV administration of this agent
 E. May cause a less coordinated, rougher recovery if administered less than 20 minutes before discontinuing inhalant anesthesia
IV. Ketamine
 A. Given as a constant rate infusion IV, this agent produces analgesia and reduces wind-up
 B. No side effects observed when given in appropriate doses to conscious horses in pain
 C. An adjunctive analgesic, not to be used as the sole analgesic agent
V. Bupivacaine
 A. Highly protein bound, long-acting local anesthetic
 B. Lasts about four times as long as lidocaine
 C. Useful for long-acting nerve blockade
 D. Produces effective analgesia if applied in the joint following arthroscopy
 E. Cardiotoxic if injected IV

Supplemental Reading

Riebold TW, Geiser De, Goble DO. *Large Animal Anesthesia: Principles and Techniques,* 2nd ed. Ames, 1995, Iowa State Press.

Craigmill AL, Rangel-Lugo M, Damian P, Riviere JE. Extra label use of tranquilizers and general anesthetics. *J Am Vet Med Assoc* 11:302-304, 1997.

Muir WW, Hubbell JAE. *Equine Anesthesia*: *Monitoring and Emergency Therapy,* 2nd ed. St Louis, 2008, Mosby

Johnston GM, Eastment JK, Wood JLN, Taylor PM. The confidential enquiry into perioperative equine fatalities (CEPEF): mortality results of Phases 1 and 2. *Vet Anaesth Analg* 29:159-170, 2002.

30 CHAPTER

Behavior

Rebecca S. McConnico

SOCIAL BEHAVIOR OF THE HORSE

I. Wild or feral horses live in two types of herds or bands
 A. Family bands (or harem bands): Made up of a group of mares and their offspring, led by a dominant male stallion. Offspring are usually younger than 3 years of age. Bands are as large as 20 herd mates or as few as three. Multimale bands have one dominant male and larger numbers. Young fillies leave the herd at the onset of sexual maturity or remain in the band and may be bred by their sires
 B. Bachelor bands are unstable in make up and vary in size from 1 to 16. Young males either leave the herd on their own, or they are run off by aggressive stallions

II. Behavior types
 A. Aggression
 1. Dominance aggression: Defined as behavior that causes injury to another or that may be followed by injury to another to establish superiority
 a. Examples of dominant behavior
 (1) Bite
 (2) Threat to bite
 (3) Head strike
 (4) Chase
 (5) Supplant
 (6) Squeel
 (7) Bunt
 (8) Tail swish
 (9) Smack
 b. Used to establish pecking order in a herd
 (1) New horse susceptible to injury when introduced into a new herd situation
 (2) Feeding stations can affect or bring out aggression
 (3) Small pasture or paddocks can contribute to aggression
 2. Pain-induced or fear aggression
 a. Horse behavior is either fight or flight. If a horse cannot flee, it will often switch to fight
 b. Common situation associated with veterinary care
 c. Veterinarian should have good restraint (halter) and then incur as little pain as possible
 d. If veterinarian-associated aggression occurs with a horse, counter conditioning or "desensitization" techniques may be effective
 (1) Desensitization involves exposing the horse to fear-inducing stimulus at a very low level that does not give the same response
 (2) Counter conditioning involves inducing a response that is behaviorally and physiologically incompatible with the undesired response (such as grooming and causing relaxation)
 3. Intermale aggression
 a. Aggression between intact males
 b. Remedied by gelding males, who will not be used for breeding
 4. Sexual aggression: Diestrous and anaestrus mares will kick, bite, or strike at males who try to come near them
 5. Maternal aggression: Foals older than a month of age begin to socialize with others and are sometimes met with aggression of mares protecting their own offspring
 6. Learned aggression
 a. Aggressive behavior followed by a given result; for example, a horse turns hindquarters toward human bringing a saddle or bridal into the stall; horse nips or nibbles when constantly given candy or treats
 b. Use positive reinforcement
 B. Affiliative
 1. Associating with other horses in general
 2. Allogrooming: Mutual grooming
 a. Withers
 b. Back
 c. Shoulder
 d. Dorsal edge of neck
 C. Sexual behavior
 1. Mare in full estrus
 2. Clitoral winking
 3. Tail raising
 4. Urination
 5. Mare may compete with another mare
 6. Stallion will have nasal or oral contact with vaginal secretions, and urine and will then show the flehmen response
 7. Stallion sexual behavior problems include ejaculatory failure, excessive aggression, low interest or slow arousal, masturbation, bouncing

the penis against the belly, sour or stale attitude, overuse or traumatic experiences, and inconsistent performance; some stallions require a specific human to become sexually aroused

D. Maternal behavior
 1. Parturition (in Northern hemisphere it occurs in April, May, June)
 a. First-stage labor: Uterine contractions are occurring before chorioallantois rupturing
 (1) Normal behavior
 (2) Extreme agitation
 (3) Trotting around the stall
 (4) Lying down, getting up repeatedly
 b. Second-stage labor
 (1) Brief, lasts 10 to 20 minutes
 (2) Rupture of chorioallantois → foal born
 c. Third stage labor
 (1) Expulsion of the placenta
 (2) Mare will lie still for several minutes → often showing signs of exhaustion or pain
 2. Postnatal behavior and nursing
 a. Mare will lick fetal membranes
 b. Mare will lick foal
 c. First half hour is critical for imprinting
 d. Mare may graze and slowly walk allowing the foal to suckle
 e. Foals nurse often and stay close to the mare
 f. Recumbent foals (resting); the mare will nurse in a circle around the foal
 g. Foal rejection
 h. Refusal of foal nursing
 (1) Commonly seen in primiparous mares
 (2) Associated with painful engorged udder
 (3) Primiparous mare does not realize that suckling will relieve the pain
 (4) May require tranquilization
 (5) May be genetically predisposed (Arabian)
 (6) Misdirected maternal behavior
 (7) Foal stealing may occur in preparturient mares

E. Developmental behavior: Prenatal and perinatal development
 1. Foals
 a. Gasp for first breath
 b. Pupil responds to light within 10 minutes
 c. Foals stands via trial and error attempts
 d. May take 15 minutes to 2 $^1/_2$ hours to stand
 e. Foal extends head and neck and opens and closes mouth
 f. Foal may stick out tongue and suck air
 2. Nursing
 a. Bobbing its head and vocalization are normal while foal learns to suckle
 b. Foal will nuzzle and bump the udder prior to nursing
 c. Mares will be aggressive to foals most often in the nuzzle-presuckle period
 d. Foal will nurse four to six times per hour
 e. Foal suckle on one teat then switches over to the other
 3. Stages of foal development
 a. Dependence = 1 month
 (1) Nursing rate and duration are highest
 (2) Recumbent rest and REM (rapid eye movement) sleep is common, as is the flehmen response
 (3) Coprophagy (up to 2 months)
 b. Socialization = 2 to 3 months
 (1) Active exploration of environment
 (2) Common contact with peers
 (3) Peak in mutual grooming
 (4) Snapping (partial exposure of the teeth, retraction of lips, rapid up and down movement of the mandibles)
 c. Developing independence = 4 months onward
 (1) Fewer and fewer dynamic socialization
 (2) Increased amounts of time resting and feeding in upright position
 d. Weaning
 (1) Final: Long period of decreasing nursing
 (2) Weaning in pairs appears to be less stressful

F. Stereotypes
 1. Morphologically identical
 2. Constantly repeated
 3. Activity does not result in consummation of a drive
 4. Causes
 a. Social isolation
 b. Restriction of movement
 c. Sterile environment (boredom, low level of sensory input)
 d. Very novel environment (high level of sensory input)
 e. Conditions that induce frustration and conflict
 f. Conditions in which key species-specific stimuli are absent
 5. Types
 a. Cribbing: Horse grasping a horizontal structure such as a fence rail, edge of a stall door, or a rim of a bucket with its incisors
 b. Tongue-lolling: Repeatedly sticking the tongue out the mouth; may curl tongue or leave the tongue out of the mouth for long periods
 c. Wind sucking (aerophagia): Swallowing air without grabbing an object with incisors
 d. Wood chewing: Grabbing the wood, biting it off, and chewing it
 e. Head-nodding: Horse raises and lowers head in a rhythm
 f. Head shaking: Functional to dislodge flies if flies are present; if flies not present, it is considered stereotypie
 g. Pawing: Constant pawing in one site
 h. Stall circling: Walking in circles around the stall
 i. Stall kicking: Repeatedly kicking the stall walls
 j. Tail rubbing: Produces hair loss and skin abrasions

k. Weaving: Constantly shifting weight from side to side
l. Bruxism: Rhythmic or spasmodic grinding of the teeth, accompanied by loud grinding sounds
(1) Foals: Usually associated with gastroduodenal ulceration
(2) Adults: May be related to pain
m. Pica
(1) Abnormal appetite for and consumption of nonfood items such as dirt, gravel, paint, or tail hairs
(2) Pica may be associated with obesity; parasitism; malnutrition; deficiencies in electrolytes, vitamins, or minerals; lack of oral stimulus; or boredom
(3) More common in foals, miniature horses, stabled horses with limited pasture, horses with high-concentrate diets or wood chewing
(4) Treatment aimed at treating the primary cause
n. Salt-eating
o. Self-mutilation
(1) Biting directed at the horse's own flank, legs, or chest
(2) Causes: Frustration associated with sexual or aggressive behaviors. Sometimes preceded by head or mouth movements or grasping at objects
p. Sleep deprivation (periodic collapse). Associated with horses that are sleep deprived for other reasons, such as abdominal discomfort, pleural discomfort, musculoskeletal disease (arthritis)

6. Treatment of sterotypies
a. Cribbing
(1) Aversion therapy
(2) Surgery: Not usually successful
(3) Buccostomy
(4) Excision of ventral branch of spinal accessory nerve
(5) Various neck muscle myectomies
b. Associated with stabling
7. Prevention
a. Regular exercise
b. Regular turnout
c. Provision of hay or roughage in diet

G. Fears and phobias
1. Trailering problems
2. Positive reinforcement
3. Spend several days to weeks acclimating the horse to a trailer
4. Desensitization
5. Consult with experienced animal handlers

H. Differences in feral and domestic horses
1. Social organization is imposed on domesticated horses
2. Geldings are present in domesticated horse population
3. Social groups are far less stable because of horses being added and taken away often
4. Groups (herds) are larger and more crowded
5. Individual horses may remain in social isolation

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 3rd ed. St Louis, 2010 (in press), Saunders.
Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St Louis, 2009, Saunders.

Cardiovascular Disease

31 CHAPTER

Rebecca S. McConnico

CARDIAC EXAMINATION

I. Locations
 A. Pericardium
 1. Infectious pericarditis
 2. Pericardial tamponade
 B. Myocardium
 1. Myocarditis
 2. Myodegeneration
 3. Myocardial fibrosis: Infective, parasitic, embolic, ischemic, monensin toxicity, vitamin E-selenium deficiency, neoplasia
 C. Cardiac valves
 1. Bacterial endocarditis
 2. Degenerative thickening of the valves
 3. Valvular dysfunction
 4. Ruptured chordae tendinae
 D. Endocardium
 E. Cardiac and vascular anomalies
 1. Patent ductus arteriosus (PDA)
 2. Atrial and ventricular septal defects (VSDs)
 3. Tricuspid or pulmonic valve atresia
 4. Complex cardiac defects

II. Function
 A. Low cardiac output
 B. Weakness
 C. Exercise performance
 D. Syncope
 E. Organ or limb ischemia
 F. Arrhythmia
 G. Secondary organ function

III. Cardiac database
 A. Signalment (age, breed, sex)
 B. History (use, exercise intolerance, fitness, drug history, complaints)
 C. Physical examination
 1. Heart rate and rhythm
 2. Arterial pulse rate, rhythm, character
 3. Jugular venous pulse and pressure
 4. Inspection for subcutaneous edema, palpation of the cardiac region
 5. Auscultation of the heart and lungs
 6. Cardiac rhythm
 7. Heart sounds
 8. Cardiac murmurs
 9. Respiratory sounds
 D. General physical examination
 E. Examination during and following work
 F. Diagnostic tests
 1. Complete blood count
 2. Coggins test
 3. Blood cultures
 4. Biochemical and cytologic examination of effusates
 5. Electrocardiogram, resting and post-exercise
 a. To determine rate, rhythm, and conduction time
 b. Lead II or base-apex: For heart rate determination
 c. P wave: Bifid (double peaked) and positive wave
 d. QRS complex
 6. Cardiac imaging
 7. Thoracic radiographs, scintigraphy, echocardiography
 8. Cardiac catheterization
 9. Angiocardiography

IV. Auscultation
 A. Cardiac rhythm
 1. Regular sinus rhythm with rate of 26 to 50 beats/min
 2. Sinus bradycardia = less than 25 beats/min and usually resulting from high vagal tone
 3. Sinus tachycardia = more than 50 beats/min
 B. Arrhythmias
 1. Physiologic arrhythmias
 a. Sinus arrhythmia
 b. Sinus block
 c. Secondary atrioventricular (AV) block is physiologic if it goes away with the administration of vagolytic drugs, startling motions, or exercise
 d. Functional systolic murmur
 2. Abnormal arrhythmias
 a. Frequent atrial premature complexes
 b. Junctional premature complexes
 c. Ventricular premature complexes
 d. Atrial tachycardia
 e. Atrial fibrillation and flutter
 C. Location of valves
 1. Mitral valve: Located at the left fifth intercostal space just dorsal to halfway point between the shoulder and sternum
 2. Aortic valve: Left fourth intercostal space just ventral to the point of the shoulder at the caudal border of the triceps muscle

3. Pulmonic valve: Left third intercostal space just ventral to the point of the shoulder and deep to the triceps muscle
4. Tricuspid valve: Left third intercostal space just dorsal to the halfway point between the shoulder and sternum deep to the triceps muscle.
5. AV valve closure: Best heard below the valves

D. Heart sounds
1. First heart sound
 a. Located at the left apex, heard best over and just below the mitral and tricuspid area
 b. The first heart sound occurs simultaneously with the apex beat and is immediately followed by the arterial pulse
 c. Initial sound represents the initial movement of the ventricle followed by AV valve closure, the opening of the semilunar valves, and finally the initial ejection of blood
2. Second heart sound
 a. Best heard over the semilunar valves, especially the pulmonic valve
 b. Associated with closure of the semilunar valves and the rapid reversal of blood flow
3. Third heart sound
 a. Noted in about half of normal horses and is best heard over the cardiac apex
 b. Associated with the end of rapid filling phase and deceleration of the rapidly filling ventricle reaching its limits of distensibility
4. Fourth heart sound
 a. Heard best at the heart base and is composed of two groups of low-frequency vibrations
 b. Associated with atrial contraction; AV blood flow is rarely audible

E. Murmurs
1. Classification of murmurs helps to identify functional from pathological murmurs and to distinguish between the different types of pathological murmur. The classification is according to the timing and duration of the murmur, its quality (pitch, change in intensity), intensity (loudness), point of maximum intensity, and radiation
2. Grading of murmurs
 a. Grade I: Softest audible murmur heard after careful auscultation in a localized area of the thorax
 b. Grade II: A faint murmur clearly audible after a few seconds of auscultation
 c. Grade III: A murmur that is immediately audible and heard over a wide area. A palpable thrill may accompany the most intense murmurs
 d. Grade IV: The loudest murmur that becomes inaudible when the stethoscope is removed from direct contact with the thoracic wall. A thrill is always present
 e. Grade V: The loudest audible murmur. It remains audible when the stethoscope is removed from direct contact with the thoracic wall. A pronounced thrill is always present
3. Murmur categories
 a. Early, mid, or late (proto, meso or telo) systolic or diastolic
 b. Pansystolic (from the beginning of S1 to the end of S2)
 c. Holosystolic (from the end of S1 to the beginning of S2)
 d. Holodiastolic (from the end of S2 to the beginning of S1)
 e. Presystolic (between the A sound and S1)
4. Changes in intensity, change in velocity of flow
 a. Murmurs associated with AV valve regurgitation have constant intensity throughout systole because the pressure gradient between the ventricles and atria remains high throughout systole; termed *plateau-type* or *band-shaped murmurs*
 b. Murmurs associated with aortic valve incompetence gradually declines during diastole because the pressure gradient between the aorta and the left ventricle falls away because of runoff into the systemic circulation and ventricle. These are termed *decrescendo murmurs*
 c. In the great arteries, the velocity of blood flow rises and falls rapidly and is greatest in early-mid systole. Consequently, murmurs associated with normal flow in these vessels increase and then decrease in intensity, are loudest in early-mid systole, and are termed *crescendo-decrescendo murmurs*
 d. Murmurs associated with a PDA are described as a waxing and waning murmur because of the changes in intensity caused by variation in the pressure gradient across the shunt

F. Murmurs in foals
1. Normal
 a. PDA: Heard for 48 to 72 hours after parturition
 b. Left heart base auscultable systolic murmurs are usually incidental; usually do not have a thrill and vary in intensity from day to day
2. Pathologic
 a. VSD. Heard best:
 (1) Right sternal border
 (2) Pulmonic valve area
 (3) Pulmonary artery
 b. Cyanosis
 (1) Respiratory distress syndrome
 (2) Pneumonia with functional cardiac murmur
 (3) Congenital heart lesion (e.g., Arabian foals); VSD with pulmonary artery atresia

G. Murmurs in mature horses (Figure 31-1)
1. Systolic murmurs
 a. Mitral or tricuspid valve regurgitation. Can be due to disease of:
 (1) Leaflets
 (2) Cusps
 (3) Chordae tendinae

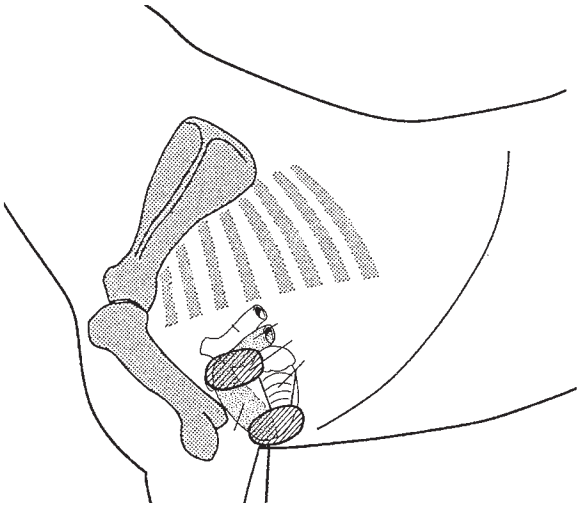


Figure 31-1 General areas for cardiac auscultation (*left side*). The typical flow murmur is loudest over the craniodorsal base (*upper oval*). Murmurs of mitral regurgitation often project loudly to the left apex (*lower oval*), although dorsal radiation is also common. (From Bonagura JD, Muir WW. The cardiovascular system. In Muir WW, Hubbell JAE, editors: *Equine Anesthesia*, St Louis, 1991, Mosby; Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.)

(4) Annulus
(5) Papillary muscles
b. Mitral insufficiency
(1) Degenerative valve disease
(2) Bacterial endocarditis
(3) Ruptured chordae tendinae
(4) Myocardial disease
c. Tricuspid valve insufficiency
(1) Pulmonary hypertension
(2) Secondary right heart enlargement
2. Diastolic murmurs
a. Aortic valve insufficiency
b. Holodiastolic murmurs
(1) Aortic regurgitation
(2) Aortic thickening: Degenerative thickening of the aortic valve
c. Congestive heart failure (CHF)
(1) Myocardial disease is the most common
(2) Congenital heart disease
(3) Pericardial effusion

V. Cardiac pharmacology
A. Digoxin (intravenous [IV] or oral): Digitalis glycosides
1. Used for CHF and supraventricular arrhythmias
2. Produce indirect neurally mediated and direct cardiac cellular actions
3. Cause augmentation of both the parasympathetic and sympathetic branches of the autonomic nervous systems
4. In patients with CHF, with digoxin treatment there is withdrawal of sympathetic tone, a decrease in peripheral vascular resistance, and an increase in cardiac output and renal blood flow
B. Quinidine: Antiarrhythmic drug
1. Produce electrophysiologic effects to restore normal sinus rhythm
2. Therapeutic concentrations of quinidine delay cardiac impulse conduction in depolarized cardiac tissues, decrease excitability, and prolong cardiac refractoriness
C. Procainamide: Antiarrhythmic drug with hemodynamic and electrophysiologic properties similar to those of quinidine
D. Lidocaine. Produces antiarrhythmic effects by:
1. Decreasing cardiac impulse conduction in depressed or diseased cardiac tissue
2. Decreasing cardiac excitatory and abnormal automaticity
3. Eliminating large disparities in myocardial refractoriness.
E. Propranolol
1. Nonspecific β-blocker and produces significant decreases in heart rate and cardiac contractility while variably affecting cardiac output when administered IV to normal adult horses
2. May cause bradycardia, muscle weakness, and depression
F. Furosemide

CARDIAC DISORDERS

I. Mitral regurgitation (MR)
A. MR is the most common valvular condition resulting in poor athletic performance in horses
B. 2/6 murmurs are unlikely to be associated with poor athletic performance
C. More widespread and louder murmurs should be regarded with suspicion
D. Animals with a grade 5/6 murmur of MR are unlikely to perform athletic work normally
E. Tachycardia and pathological arrhythmias, particularly atrial fibrillation, may be present if marked volume overload results from the valvular incompetence
F. Patients with moderate or severe MR are likely to start a race normally but tire quickly
G. Epistaxis is observed in some cases during exercise after pulling up
H. Marked tachycardia and tachypnea
I. The recovery period is usually prolonged
J. Echocardiography is the best method of assessing the severity of grade 3 and 4 murmurs

II. Aortic insufficiency (AI)
A. Horses with AI perform normally
B. May be responsible for poor athletic function
C. If determined to be associated with another abnormality, performance will likely be restricted
D. The murmur associated with AI can be extremely loud (even grade 5 or 6) in horses with normal exercise tolerance

E. If sudden onset, it is more likely to affect race times
F. Other causes of poor performance should also be investigated

III. Tricuspid regurgitation
A. Common in National Hunt racehorses that have a normal performance history
B. Considered an incidental finding when it is detected in a horse presented for poor athletic performance
C. Other causes of poor performance should be investigated

IV. Congenital heart disease
A. Complex congenital heart disease is incompatible with athletic performance
B. Small restrictive VSDs are found in normal successful athletes
C. Normal right ventricular size, normal interventricular septal motion, and a defect of less than 2.0 to 2.5 cm are good prognostic signs

V. Atrial fibrillation
A. The most common arrhythmia to cause poor athletic performance
B. Treatment is usually required for recovery to normal performance levels
C. Successful treatment with no significant underlying heart disease may result in a normal race career; it is likely that the horse will return to previous levels of performance
D. Can be very difficult to diagnose if paroxysmal.
E. Atrial premature complexes, atrial tachycardia, and ventricular arrhythmias
F. Atrial premature contractions and ventricular premature contractions may be observed during a routine clinical examination or during heart rate slowing after exercise

VI. Myocarditis
A. Myocarditis may be suspected if arrhythmias are detected
B. Investigation should include echocardiography to assess myocardial function and identification of any other conditions that predispose to arrhythmias

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St. Louis, 2004, Saunders.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St. Louis, 2008, Mosby.

32 CHAPTER

Hematology

Rebecca S. McConnico

ANEMIA

I. Regenerative anemia
 A. Horses do not release reticulocytes into circulation in response to an acute hemorrhagic or hemolytic episode
 B. Increased mean cell volume and red cell distribution width after hemorrhage or hemolysis are unreliable indicators of regeneration
 C. Best method of assessing the equine erythroid regenerative response is determination of bone marrow myeloid-erythroid (M:E) ratio or bone marrow reticulocyte count
 1. M:E ratio of 0.5 is consistent with erythrocyte regeneration
 a. Normal equine marrow contains approximately 3% reticulocytes
 b. Following acute severe hemorrhage, this may increase to 66%
 2. If bone marrow analysis is not an option, peripheral blood packed cell volume (PCV) may be monitored to assess regeneration. Accelerated bone marrow red cell production should be evident by 3 to 7 days after acute hemorrhage, with an average increase in PCV of 0.5% to 1.0% per day

II. Causes of regenerative anemia
 A. Blood loss
 B. Red blood cell (RBC) destruction
 1. Immune mediated
 2. Neonatal isoerythrolysis
 3. Heinz body anemia (oxidative damage)
 4. RBC parasites

III. Intravascular vs. extravascular hemolysis
 A. Intravascular hemolysis
 1. Hemoglobin from the lysed erythrocytes is released directly into the plasma
 2. Excess hemoglobin is bound to haptoglobin
 3. As the binding capacity of haptoglobin is exceeded, gross hemoglobinemia develops
 4. Some excess hemoglobin is taken up by mononuclear phagocytes and metabolized to bilirubin
 5. Other hemoglobin is filtered through the renal glomerulus, resulting in hemoglobinuria and potential renal tubular damage
 6. Plasma hemoglobin concentrations are approximately one third of the PCV
 7. Intravascular hemolysis → plasma hemoglobin concentration exceeds one third of the PCV and plasma bilirubin concentrations are increased
 8. Intravascular hemolysis → increased mean corpuscular hemoglobin (MCH) and MCH concentration
 B. Extravascular hemolysis
 1. Damaged RBCs are removed from circulation by mononuclear phagocytes
 2. Gross hemoglobinemia and hemoglobinuria do not occur
 3. Hemoglobin is degraded directly into bilirubin inside the phagocytic cell, and serum bilirubin concentrations increase

IV. Blood loss
 A. There are many causes of blood loss; most are evident
 B. Treatment of acute severe hemorrhage (loss of 15% to 30% of total blood volume)
 1. The most important aspects of therapy are controlling the hemorrhage and replacing blood volume
 a. Apply direct pressure to the site or ligate the offending vessel(s)
 b. Control of internal hemorrhage
 2. Use some form of volume replacement therapy if the horse is tachycardic with poor peripheral perfusion
 a. Hypertonic saline: Hypertonic saline at 4 to 6 mL/kg administered IV over 15 minutes, followed within a few hours by isotonic fluid administration in sufficient quantity to replace estimated total body fluid deficits
 b. Isotonic fluids: Total volume should exceed the estimated volume of blood loss by a factor of 2 to 3
 c. Whole-blood transfusion: ~1 mL of whole blood/lb of body weight should increase the recipient horse's PCV by 1%. Therefore, 1 L of whole blood should increase the PCV of a 450 kg horse by approximately 1%

V. Heinz body anemia
 A. Acute or chronic RBC destruction
 1. Caused by oxidative denaturation of hemoglobin with subsequent formation of Heinz bodies within the RBCs
 2. Produces cells that are readily removed from the circulation by either intravascular hemolysis or via macrophages as part of the reticuloendothelial system

B. Pathophysiology
 1. Known toxins, drugs, and chemicals associated with Heinz body production function as electron acceptors and act as an artificial link between cell components and the direct oxidative action of molecular O_2 in the RBCs
 2. Denatured hemoglobin formed through this reaction precipitates in the form of Heinz bodies and attaches to the RBC membrane, causing either loss of critical ionic composition with resultant intravascular hemolysis or deformability changes with subsequent premature RBC removal by the spleen
C. Clinical signs
 1. May affect any age, sex, or breed but is uncommon in adults
 2. Exercise intolerance
 3. Weakness
 4. Pale or icteric mucous membranes
 5. With or without fever
 6. With or without tachypnea
 7. With or without tachycardia
 8. Holosystolic heart murmur
 9. Abdominal pain (ischemia)
 10. Hemoglobinuria
 11. Rectal examination: Enlarged spleen
 12. Severe debilitation and death in severe cases
 13. Necropsy: Enlarged liver and spleen; pale or icteric tissues
D. Causes
 1. Toxicosis
 a. Phenothiazine
 b. Wilted red maple leaves
 (1) Leaves contain an uncharacterized toxin that oxidizes ferrous (Fe++) iron in the normal hemoglobin molecule to the ferric (Fe+++) form
 (2) Ferric form of hemoglobin, known as methemoglobin, is incapable of carrying oxygen to the tissues
 (3) Normal blood methemoglobin concentration is less than 1%. Horses that have ingested wilted red maple leaves may have methemoglobin concentrations greater than 25%. Excess methemoglobin results in a brownish discoloration to blood and tissues. Oxidant stress to erythrocytes also results in the formation of disulfide linkages in the protein component of the hemoglobin molecule with resultant denaturation and precipitation of the molecule. Denatured hemoglobin is seen as spherical, refractile Heinz bodies attached to the erythrocyte membrane. Heinz bodies increase osmotic fragility, resulting in intravascular hemolysis and may also enhance cell clearance from circulation by mononuclear phagocytes
 c. Wild onions
 2. Antigen: RBCs
E. Diagnosis
 1. Differential diagnosis
 a. Hemorrhage
 b. Heinz body anemia (red maple leaf toxicosis, onion toxicosis, phenothiazine toxicosis)
 c. Equine infectious anemia
 d. Equine piroplasmosis
 e. Equine granulocytic ehrlichiosis
 f. Lymphosarcoma
 g. Purpura hemorrhagica
 2. Complete blood cell count (CBC), biochemistry, and urinalysis
 a. PCV less than 20%
 b. Heinz bodies on direct blood smear
 c. With or without neutrophilic leukocytosis
 d. Negative Coombs' test
 e. Elevated total bilirubin (indirect >>>> direct)
 f. Increased MCH suggests the presence of intravascular hemolysis
 g. Bilirubinuria
 h. Occult blood positive (no microscopic hematuria)
 3. Other laboratory tests
 a. Negative direct antiglobulin test (Coombs')
 b. Increased osmotic fragility
 c. Bone marrow aspirate reveals a diffuse regenerative erythron (M:E ratio less than 0.5)
 d. Heinz bodies are best visualized with new methylene-blue stain of a wet-mount preparation of blood (Heinz bodies appear as bluish green, oval-to-serrated refractile granules located near RBC margin or protruding from the cell)
 e. Elevated blood urea nitrogen (BUN) level if hemoglobinuric nephrosis is present
 f. Methemoglobin test if mucous membranes or urine are brown-tinged
 4. Imaging
 a. Splenic-hepatic ultrasound: Splenic or hepatic enlargement; may show hyperechoic or hypoechoic. Some loss of architecture as a result of increased fluid component
 b. Radiographs: Thorax is usually within normal limits
 5. Pathologic findings
 a. Necropsy: Enlarged liver and spleen; pale or icteric tissues
 b. If chronic, may see signs of congestive heart failure (CHF) (pulmonary embolism, pulmonary edema, cardiomegaly, hepatic congestion)
 6. Treatment
 a. Identify and remove the source of oxidant
 b. Cross-matched blood transfusion if clinically indicated (evidence of tissue hypoxia, usually PCV less than 8% to 12%)
 c. PCV should be monitored closely for development of life-threatening anemia
 d. Intravenous (IV) fluid therapy is indicated to prevent pigment nephropathy
 e. Oxygen therapy may be useful but often is ineffective if hemoglobin O_2-carrying capacity is too low
 f. Nursing care (e.g., catheter asepsis)

g. Minimize activity but allow the animal to have access to fresh air and sunshine if possible. No forced exercise
h. Diet: Balanced diet with good quality hay and grain
i. Fresh water should be available *ad libitum*
j. Medications: There is no specific medicinal treatment for Heinz body anemia
k. Contraindications: It may be detrimental to use methylene-blue or other reductive therapy as these may enhance Heinz body formation
l. IV vitamin C may be useful in cases involving methemoglobin-associated conditions

7. Adverse side effects include laminitis, nephrosis, general debilitation, and abortion
8. Prognosis: If inciting cause can be removed and methemoglobinemia is minimal, prognosis for recovery is fair to good. Several weeks may be required for full recovery

VI. Immune-mediated anemia
A. Acute or chronic RBC destruction due to antierythrocyte antibody coating of RBCs and subsequent intravascular lysis or phagocytosis by macrophages of the reticuloendothelial system.
B. Pathophysiology
1. RBC membrane attenuation → induction of formation of antibodies → immune complexes bind to RBC membrane → intravascular or extravascular hemolysis. Antierythrocyte antibody or immune complexes are formed as a result of sensitization to an exogenously administered drug or antigens from pathogenic microorganisms. Neoplasia can result in cross-reacting antibody to tumor antigen or abnormal antibody production by neoplastic cells
2. Renal-urologic: Possible pigment nephropathy
3. Common in foals (neonatal isoerythrolysis)
4. Uncommon in adults
5. May affect any age, breed, or either sex
C. Clinical signs
1. Exercise intolerance
2. Weakness
3. Pale or icteric mucous membranes
4. With or without fever
5. With or without tachypnea
6. With or without tachycardia
7. Holosystolic heart murmur
8. Abdominal pain (ischemia)
9. Hemoglobinuria
10. Rectal examination: Enlarged spleen
11. Severe debilitation and death in severe cases
D. Necropsy: Enlarged liver and spleen; pale or icteric tissues
E. Causes
1. Primary immune-mediated: Neonatal isoerythrolysis
2. Autoimmune hemolytic anemia, incompatible blood transfusion
3. Secondary immune-mediated
a. Toxicosis: Phenothiazine, wilted red maple leaves, wild onions
b. Infectious: Equine infectious anemia (EIA)
c. Piroplasmosis, equine granulocytic ehrlichiosis
d. Neoplastic: Lymphosarcoma, others
e. Drug-associated: Penicillins, cephalosporins, sulfas. Drugs known to have caused secondary immune-mediated hemolytic anemia (IMHA) should be avoided in the future
f. Microangiopathic (disseminated intravascular coagulation [DIC])
F. Differential diagnosis
1. Hemorrhage
2. Heinz body anemia (red maple leaf toxicosis, onion toxicosis, phenothiazine toxicosis)
3. Neonatal isoerythrolysis (neonates)
4. Equine infectious anemia
5. Equine piroplasmosis
6. Equine granulocytic ehrlichiosis
7. Lymphosarcoma
8. Purpura hemorrhagica,
G. CBC, biochemistry, and urinalysis
1. PCV less than 20%, with or without neutrophilic leukocytosis
2. Positive Coombs' test
3. Elevated total bilirubin (indirect >>>> direct)
4. Increased MCH suggests the presence of intravascular hemolysis
5. Bilirubinuria
6. Occult blood positive (no microscopic hematuria)
7. Positive direct antiglobulin test (Coombs')
8. In-saline autoagglutination
9. Increased osmotic fragility
10. Bone marrow aspirate reveals a diffuse regenerative erythron (M:E ratio less than 0.5)
11. Signs consistent with DIC
12. Positive serologic titer for infectious causes
13. Evidence of hematologic parasites on direct blood smears
H. Imaging
1. Splenic-hepatic ultrasound: Splenic-hepatic enlargement; may show hyperechoic or hypoechoic. Some loss of architecture resulting from increased fluid component
2. Radiographs: Thorax is usually within normal limits unless there is a primary neoplasia
I. Thorough diagnostic workup to rule out neoplasia and infectious causes of secondary immune-mediated response
J. Pathologic findings
1. Necropsy: Enlarged liver and spleen; pale or icteric tissues
2. If chronic, may see signs of CHF (pulmonary embolism, pulmonary edema, cardiomegaly, hepatic congestion)
K. Treatment
1. Appropriate health care
2. Cross-matched blood transfusion if clinically indicated (evidence of tissue hypoxia, usually PCV less than 8% to 12%)
3. IV fluid therapy if indicated and horse is not drinking

4. Discontinuation of current medication to rule out drug-associated IMHA
5. Splenectomy may be considered if primary cause cannot be identified (last resort)
6. Drugs of choice: Glucocorticoids
 a. Dexamethasone phosphate 0.04 to 0.2 mg/kg IV or intramuscularly every 12 to 24 hours, then a decreasing dose program of prednisolone (2 to 3 mg/kg)
 b. Corticosteroids may exacerbate infectious causes of secondary IMHA
 c. PCV should be carefully monitored and the dose rate of dexamethasone increased to twice daily if the PCV does not stabilize within 24 to 48 hours

L. Adverse side effects
 1. Pigment nephropathy
 2. Laminitis

M. Prognosis
 1. If the primary cause of the anemia can be identified and successfully treated, prognosis for IMHA is good. RBCs will replenish as the immune-mediated response resolves. This may take up to several weeks in some patients
 2. Horses requiring constant corticosteroid treatment may have an incurable underlying disease. The prognosis for these horses is poor

VII. Neonatal isoerythrolysis
 A. Alloantigens: The blood type or antigenic components on the surface of a horse's RBCs are derived from the combined genetic input of that horse's sire and dam
 B. Genes are codominant
 C. Alloantigens inherited from each parent are simultaneously expressed in the offspring
 D. If a mare is exposed to blood factors that are not normally present on her own blood cells, she will develop alloantibodies against that foreign antigen
 E. Exposure to foreign blood group antigens may occur
 1. At birth
 2. During pregnancy
 3. During parturition
 4. After a transfusion
 5. As the result of administration of biologics of equine origin
 F. As parturition approaches, the mare concentrates immunoglobulin (including alloantibodies) in her colostrum. After the foal is born, the immunoglobulin-rich colostrum is ingested and alloantibodies reach the foal's blood. If the foal has inherited an incompatible alloantigen from the sire, absorbed alloantibodies will attach to circulating RBCs. The result is severe intravascular or extravascular hemolytic anemia in the foal
 G. There are seven major blood group systems in horses, but the vast majority of neonatal isoerythrolysis is due to incompatibility of blood types
 1. Aa
 2. Qa

COAGULATION DISORDERS

I. Pathophysiology: Acquired disorders characterized by the inability to form a stable fibrin clot that causes loss of blood from the vasculature
 A. Vasculitis: Immune-mediated or hypersensitivity vasculitis is due to response to antigenic stimulus usually induced by a microbe, drug, toxin, or protein. Immune complex deposition in vessel walls will cause complement activation and chemoattractant production
 1. Purpura hemorrhagica
 2. Immune-response secondary to infection with:
 a. Equine ehrlichiosis
 b. EIA
 c. Immune-mediated anemia
 d. Equine viral arteritis (EVA)
 e. Eastern equine encephalitis (EEE)
 f. Influenza
 g. Streptococcus
 B. Platelet defects
 1. DIC
 2. End-stage hepatic disease
 3. Renal failure
 C. Coagulation defects: Idiopathic thrombocytopenic purpura (ITP)
 D. Anticoagulant toxicosis (warfarin, brodifacoum, bromodiolone, diphacinone, moldy sweet clover [dicoumarin])
 1. First- and second-generation anticoagulant rodenticides act on the enzyme vitamin K epoxide reductase, an enzyme required for production of vitamin-K–dependent clotting factors (II, VII, IX, and X)
 2. Vitamin K epoxide reductase is necessary for recycling vitamin K; when it is inhibited, body stores of vitamin K are diminished, synthesis of vitamin K–dependent clotting factor ceases, and, eventually a hemorrhagic crisis develops
 3. Small repeated doses are more serious, although a single ingestion may be lethal

II. Signalment
 A. Any sex
 B. Any breed
 C. Any age

III. Clinical signs
 A. Vasculitis
 1. Petechial and ecchymotic hemorrhages and hyperemia are common
 2. Demarcated areas of dermal or subcutaneous edema, some severe enough to cause skin, muscle, or organ infarction, necrosis, and exudation
 3. Fever
 4. Swollen limbs
 5. Parenchymal (liver, kidney, pulmonary) infarcts
 6. Myopathy
 B. Platelet disorders (e.g., ITP) and vitamin K–dependent clotting dysfunction
 1. Diffuse hemorrhaging from small blood vessels, characterized by petechial hemorrhages on the mucosal membranes, third eyelid, or sclera

2. Epistaxis, occult melena, hyphema, and hematuria are not uncommon
3. Prolonged bleeding from wounds or injection sites is not unusual
4. Dyspnea and coughing may be observed if there is pulmonary involvement

IV. Differential diagnosis
A. Vasculitis: EIA, EVA, EEE, purpura hemorrhagica
B. Anticoagulant rodenticide toxicosis: Congenital coagulation disorders (hemophilia); immune-mediated thrombocytopenia, infectious viral disease (EVA, EIA)

V. Diagnosis
A. CBC, chemistry, urinalysis
1. Vasculitis: Neutrophilia, mild anemia, hyperglobulinemia, hyperfibrinogenemia, moderate to severe anemia, thrombocytopenia in many cases, elevated creatine phosphokinase and aspartate aminotransferase in cases with myopathy, elevated BUN, or creatine in cases of pigment or vasculitis-associated nephropathy
2. Anticoagulant rodenticide toxicosis: Anemia (mild to marked)

B. Other tests
1. For vasculitis
a. Serology for equine influenza virus, EVA, EIA, EEE
b. Full-thickness skin punch biopsies (preserved in Michel's media) show neutrophilic infiltration of venules in dermal and subcutaneous tissues. Also present is leukocytoclasis and fibrinoid necrosis. Immunofluorescence may show immune complexes
2. For rodenticide exposure
a. Serum prothrombin time (PT) and partial thromboplastin time (PTT) should be monitored daily for 2 to 4 days, then, twice weekly after PT and PTT have normalized
b. Activated coagulation time, which is a simplified variation of the PTT, may be more useful for clinicians. Continuous monitoring of clotting profile (PT, PTT, activated coagulation time, platelet count)

C. Imaging
1. Vasculitis
a. Thoracic radiographs may reveal pulmonary infiltrate suggestive of hemorrhage or infarcted lung
b. Ultrasonography: Areas of hypoechogenicity in muscle or parenchymal tissues indicating hemorrhage or edema
2. Anticoagulant rodenticide or moldy sweet clover ingestion
a. Tissue hemorrhage (pulmonary infiltrate, hemothorax) may be observed on thoracic radiographs
b. Ultrasound examination may show areas of hypoechogenicity (kidney, liver, spleen)

D. Pathologic findings
1. Tissue hemorrhage
2. Icteric tissues (if chronic in nature)

VI. Treatment
A. Appropriate health care
1. Mainly aimed at support
2. Expeditious treatment with vitamin K1 in cases of anticoagulant rodenticide toxicosis
3. Vasculitis: If immune-mediated component is determined, corticosteroid therapy may be indicated; see under IMHA treatment for regimen (EIA and other viral causes may be exacerbated with corticosteroid therapy)
4. Minimize trauma and venipunctures, minimize exercise
5. Surgery is contraindicated
6. Feed alfalfa hay as a good source of Vitamin K

B. Medications: Oral or subcutaneously administered vitamin K1 (2.5 mg/kg at 12-hour intervals). Treatment should be continued for 1 week (first-generation anticoagulant exposure, e.g., warfarin) or 3 to 5 weeks (second-generation anticoagulant rodenticide, e.g., brodifacoum) with continued monitoring of PT and PTT when vitamin K treatment has been discontinued

C. Contraindications. Drugs that may interfere with vitamin K1 binding include
1. Phenylbutazone
2. Oxyphenbutazone
3. Heparin, phenytoin
4. Salycilates
5. Quinidine
6. Potentiated sulfas
7. Steroid hormones
8. Do *not* use menadione (vitamin K3) in horses because it can cause renal failure

VII. Possible complications and prognosis
A. Possible secondary infections (pneumonia) caused by pulmonary hemorrhage or other tissue hemorrhage
B. Good to fair prognosis if recognized and treated early (vasculitis and rodenticide anticoagulant toxicosis)
C. Some horses may be nonresponsive and die if condition is not recognized and treated appropriately
D. Rodenticides may pass through the placenta and cause coagulation defects in fetus

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.
Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 3rd ed. St Louis, 2010 (in press), Saunders.
Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

33 CHAPTER

Dermatology

Elizabeth Rustemeyer May

PRURITIC SKIN DISORDERS OF HORSES

I. Parasitic disorders
 A. Mites
 1. Chorioptic mange (leg mange)
 a. *Chorioptes equi*
 b. Common surface-inhabiting mite
 c. Transmission via direct contact; not zoonotic
 d. Clinical signs
 (1) Pruritus of fetlocks and pasterns
 (2) Can extend to involve the tail and perineum
 (3) Typically a primary papular eruption
 (4) Secondary pyoderma is extremely common resulting from self-trauma associated with pruritus
 e. Diagnosis
 (1) Compatible clinical signs
 (2) Skin scrapings, superficial and deep (Figure 33-1)
 f. Treatment
 (1) Lime sulfur, organophosphate dips, selenium sulfide
 (2) Ivermectin
 (3) Fipronil spray
 (4) Treat contact animals



Figure 33-1 Chorioptes mite (100×). (From Scott DW, Miller WH. *Equine Dermatology.* St Louis, 2003, Saunders.)

 (5) Control pruritus and treat secondary infections with appropriate antibiotic therapy
 2. Sarcoptic mange
 a. *Sarcoptes scabiei* var. *equi* mite
 b. *This is a reportable disease in the United States*
 c. Clinical signs
 (1) *Extremely* pruritic
 (2) Intense mane and tail pruritus
 d. Treatment: Systemic therapy
 (1) Ivermectin
 (2) Lime sulfur dip
 3. Psoroptic mange. Pruritic dermatitis or pruritic otitis
 a. Non-burrowing mites
 b. Live on skin surface, under crusts
 c. Begins as mane and tail pruritus but can become generalized
 d. Treatment: Ivermectin
 B. Pediculosis (lice infestation)
 1. Lice are species specific
 a. Anoplura
 (1) *Haematopinus asini*—sucking louse
 (2) Favor the mane, tail, and fetlock
 b. Mallophaga
 (1) *Bovicola equi*—biting louse
 (2) Prefer the dorsolateral trunk
 2. Transmitted via direct contact
 3. Clinical signs consistent with pruritus and chronic self-trauma
 4. Easily diagnosed with direct visualization or tape cytology and microscopic examination
 5. Treatment
 a. Provide sound nutrition and avoid overcrowding
 b. Most parasiticides will kill lice
 c. Treat all in-contact animals
 C. Culicoides hypersensitivity
 1. Very common
 2. Type I hypersensitivity—thought to be hereditary
 3. Many species exist; all feed at night
 4. Occurs seasonally
 a. Symptoms may worsen each subsequent year
 b. Lesions secondary to pruritus
 5. Diagnosis: Clinical signs, intradermal allergy testing

6. Treatment
 a. Stable management
 b. Prevent exposure

D. Insect hypersensitivity
1. *Simulium* spp. = blackfly
2. *Tabanus* spp. = horse fly
3. *Stomoxys calcitrans* = stable fly
4. *Haematobia* spp. = horn fly

II. Atopy (atopic dermatitis)
A. Inherited predisposition for the development of hypersensitivities to environmental allergens associated with the production of allergen-specific immunoglobulin E (IgE) antibodies
B. Type I hypersensitivity disorder
C. Not well documented in the horse
D. Development of clinical signs requires a second exposure (the challenge) following the initial exposure (sensitization). Allergen-specific IgE is produced in response to exposure to a previously encountered allergen
E. Clinical signs
1. Seasonal to nonseasonal pruritus
2. Most lesions secondary to self-trauma
F. Diagnosis: Pruritus is the hallmark of this disease
1. Rule out other pruritic causes of skin disease
2. This is a diagnosis of exclusion
3. Allergy testing (intradermal testing) is used to determine any allergies the animal has, not to diagnose atopy
G. Treatment
1. Avoid the allergen if possible
2. Hyposensitization vaccine therapy
3. Corticosteroids are very effective when used correctly and judiciously
4. Antihistamines can be used in combination with fatty acids or corticosteroids to use lower doses of corticosteroids in some animals
5. Topical antipruritic and bathing therapy will help decrease allergen exposure

III. Adverse reaction to food (food allergy)
A. Mechanism of disease is not currently known
B. This is not well documented in the horse
C. Diagnosis
1. Elimination diet trial
2. Decrease in pruritus of 50% or greater
3. Diagnosis confirmed by increase in pruritus with food challenge
D. Treatment
1. Avoid the offending dietary allergen
2. Some animals will respond to antihistamine or fatty acid therapy

IV. Focal ventral midline dermatitis
A. Seasonal: Spring to fall
B. Mechanical irritation from biting flies. *Haematobia* spp. = horn fly
C. Well-demarcated area of lichenification, ulceration, crusts around the umbilicus
D. Diagnosis
1. History and clinical signs
2. Rule out other causes
E. Treatment
1. Treat secondary infections
2. Prevent fly exposure

SCALING AND CRUSTING DISORDERS

I. Infectious disorders
A. Bacterial causes
1. Dermatophilosis (rain rot)
 a. Common in horses
 b. *Dermatophilus congolensis*
 c. Only known source is other animals; however, this is not considered a highly contagious disease
 d. For an infection to develop must have
 (1) Moisture
 (2) Skin microtrauma
 e. Clinical signs
 (1) Thick crusts with matted hair (paintbrush crusts)
 (2) Eroded skin surface below crusts when removed
 (3) Lesions are often painful but can also become pruritic
 (4) Photodermatitis in nonpigmented areas
 f. Diagnosis
 (1) Cytology of crust material
 (2) Branching organism can be identified microscopically (Figure 33-2)
 (3) Culture may be required
 g. Treatment
 (1) Systemic antibiotic therapy
 (2) Topical antiseborrheic and antimicrobial shampoos
2. Bacterial folliculitis and furunculosis
 a. Typically caused by *Staphylococcus aureus* or *Staphylococcus pseudintermedius*
 b. Secondary to skin microtrauma
 c. Classifications

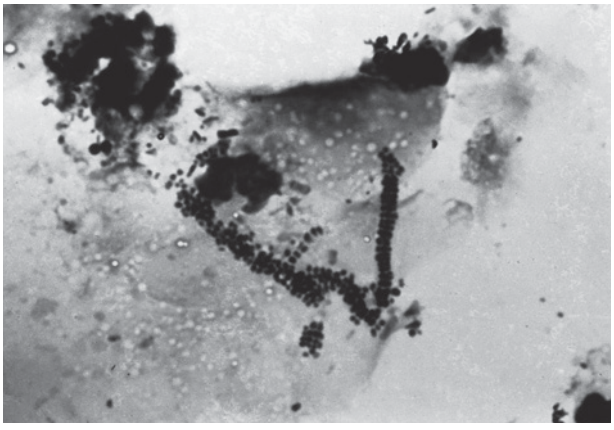


Figure 33-2 Dermatophilosis. Coccoid organisms are present as branching filaments ("railroad tracks"). (From Scott DW, Miller WH. *Equine Dermatology*. St Louis, 2003, Saunders.)

(1) Truncal folliculitis and furunculosis (saddle rash)
(a) Papules to nodules beginning in the saddle area
(b) Typically occurs during warmer weather
(2) Pastern folliculitis
(a) Restricted to the pasterns and fetlocks
(b) Papules, crusted papules, pustules
(3) Tail pyoderma. Lesions may develop secondary to tail rubbing
d. Diagnosis
(1) Cytology
(2) Rule out other causes of folliculitis
(3) Culture and sensitivity may be necessary with deeper lesions
e. Treatment
(1) Topical antimicrobial shampoos
(2) Oral antibiotics

B. Fungal causes. Dermatophytosis
1. Fungal organisms invade keratinized structures
2. This can be a self-limiting disease, depending on the immune status of the host
3. These infections are rarely zoonotic
4. Transmission via contact with an infected host, fomite, or contaminated environment
5. Clinical signs
a. Minimal to extensive inflammation with scaling and alopecia
b. Variable pruritus (girth itch)
c. Mane and tail rarely affected
6. *Trichophyton equiinum*, *T. mentagrophytes*, *T. verrucosum*, *Microsporum gypseum*, *M. canis*
7. Diagnosis
a. Fungal culture
b. Trichogram
8. Treatment
a. Most will resolve spontaneously unless immunocompromised
b. Avoid combination products containing corticosteroids
c. Whole-body treatments required
(1) Lime sulfur dip
(2) Miconazole or ketoconazole shampoos
(3) Systemic therapy very expensive
d. Environmental decontamination is also important

C. Parasitic causes
1. Demodicosis (demodectic mange): Can present as a scaling and alopecic disease; however, the nodular form is much more common
2. Cutaneous onchocerciasis
a. *Onchocerca cervicalis* microfilaria transmitted between horses via *Culicoides* exposure
b. Most pruritus associated with onchocerciasis is actually due to the bite of *Culicoides*
c. Presence of microfilaria in the skin does not cause clinical signs unless a hypersensitivity reaction occurs
d. Clinical signs
(1) Inflammatory facial lesions
(2) Ventral dermatitis
(3) Depigmentation
(4) Scarring alopecia
e. Diagnosis
(1) Histopathology
(2) Response to treatment
f. Treatment: Ivermectin

II. Allergic and immunologic causes

A. Irritant contact dermatitis
1. Considered an inflammatory reaction to an irritating substance rather than an immunologic reaction like contact allergy
2. Typically multiple animals are affected
3. Much more common than contact allergy
4. Irritating substances associated with irritant contact dermatitis include insect repellants, parasiticides, detergents
5. Clinical signs
a. Thinly haired areas
b. May be painful rather than pruritic
6. Diagnosis: Based on history and physical examination
7. Treatment
a. Remove the irritating substance by bathing
b. Avoid the irritating substance

B. Contact dermatitis
1. Rare cause of skin disease
2. Usually only one animal affected
3. Typically occurs in thinly haired body regions since hair provides excellent protection
4. Cell mediated hypersensitivity reaction (type IV) requires prior sensitization to the allergen
5. Clinical signs
a. Mild to moderate pruritus
b. Secondary lesions and pyoderma from self-trauma
6. Diagnosis
a. Rule out other causes via history, clinical signs, distribution of lesions
b. Identify substances to perform patch testing or a challenge based on environmental history
7. Treatment
a. Avoid the allergen
b. Topical corticosteroids if required
c. Treat the secondary bacterial infection if present
d. Pentoxifylline orally

C. Pemphigus foliaceus
1. Autoimmunity, or loss of tolerance for "self" tissues
2. Characterized by subcorneal to intraepidermal pustules—superficial layers of the epidermis—resulting in crusts covering erosions or ulcers
3. Very similar to the disease seen in dogs

4. Common areas of the body affected include the face, head, and coronary band
5. Diagnosis is made via skin biopsy for histopathology
6. Treatment
 a. Immunosuppressive doses of corticosteroids
 b. Other immunosuppressive agents, such as gold salts

III. Environmental causes: Actinic dermatitis
A. Lesions induced by solar damage = sunburn
B. Photosensitivity: Associated with substances that absorb energy from ultraviolet (UV) light causing tissue damage
1. Phototoxic agents—ingestion of photoactive substances
2. Photoallergic agents—require prior exposure
C. Clinical signs
1. Erythema, scaling, crusting of the nonpigmented areas (white skin and hair)
2. Photosensitization involves sunburn symptoms plus necrosis, ulceration, and pain affecting nonpigmented areas
3. Photoactivated vasculitis—massive edema
D. Diagnosis
1. History and physical examination
2. Clinical signs
3. Screening lab work for liver disease
4. Skin biopsy for histopathology
E. Treatment
1. Avoid UV light
2. Stop ingestion of photoactive substances if occurring
3. Corticosteroids

IV. Keratinization disorders: Mane and tail seborrhea
A. Very minimal pruritus
B. Diagnosis of exclusion
C. Treatment includes topical antiseborrheic shampoos

V. Miscellaneous causes: Pastern dermatitis (grease heel, scratches)
A. Multiple causes
B. Typically a combination of causes
C. Diagnosis requires a very thorough workup
D. Treatment depends on the underlying cause

NODULAR SKIN DISORDERS

I. The main differential diagnoses for these lesions include infectious causes, neoplasia, or sterile inflammatory causes

II. Infectious causes

III. Bacterial causes
A. Abscesses
1. *Corynebacterium pseudotuberculosis*—zoonotic concerns
2. *Streptococcus equi*
3. *Clostridium* spp.
4. *Staphylococcus* spp.
5. Diagnosis
 a. Cytology
 b. Culture and sensitivity
6. Treatment
 a. Lance abscess
 b. Antibiotic therapy
B. Ulcerative lymphangitis
1. *C. pseudotuberculosis*—zoonotic concerns
2. *C. equi, Streptococcus* spp., *Staphylococcus* spp.
3. Secondary to wound contamination
4. Clinical signs
 a. Sudden onset of leg edema
 b. Multiple nodules that ulcerate and drain (corded lymphatics)
5. Diagnosis
 a. Cytology
 b. Culture and sensitivity
 c. Histopathology
6. Treatment
 a. Systemic antibiotic therapy
 b. Hydrotherapy

IV. Fungal causes
A. Sporotrichosis
1. Zoonotic disease
2. *Sporothrix schenckii*
3. Cutaneolymphatic form most common in the horse
4. Diagnosis
 a. Cytology
 b. Histopathology
 c. Culture
5. Treatment: Sodium iodide
B. Pythiosis
1. Not truly a fungal organism
2. Very pruritic lesions
3. Requires warm temperatures and moisture to invade damaged skin
4. Gulf Coast states typically
5. Diagnosis
 a. Histopathology
 b. Polymerase chain reaction testing
6. Treatment: Very difficult to treat successfully

V. Viral causes. Aural plaques (ear papillomas)
A. Lesions affecting the inner surface of the pinna caused by a papilloma virus
B. One to several hyperkeratotic plaques
C. These are nonpruritic and nonpainful
D. Diagnosed by classic clinical appearance
E. Cosmetic defect—currently no effective treatment

VI. Parasitic causes
A. Demodicosis
1. Rare in the horse
2. *Demodex equi*
3. Nodular dermatitis affecting the face and neck as well as the shoulders
4. Diagnoses via examination of material within the nodules, skin scrapings of affected areas
5. Look for an underlying cause
6. No effective therapy
B. Cutaneous habronemiasis (summer sores)
1. This is an aberrant parasitism that occurs only in the horse
2. *Habronema muscae*
3. *Habronema majus*
4. *Draschia megastoma*

5. Larvae gain access to the deep layers of the skin rather than following the normal pathway to the stomach
6. Larvae must be deposited in abnormal skin
7. Lesions form as a result of a hypersensitivity reaction
8. Clinical signs
 a. Seasonal
 b. Medial canthus of the eye, male genitalia, lower extremities
 c. Ulceration with granulation tissue
 d. Variable pruritus
9. Diagnosis:
 a. History, physical examination
 b. Histopathology
10. Treatment:
 a. Corticosteroids to reduce the size of the lesion
 b. Prevent reinfection with fly control

VII. Allergic and immunologic causes
- A. Urticaria
 1. Extremely common
 2. Type I hypersensitivity
 3. Many cases are idiopathic
 4. Other causes include drug reactions, allergens such as environmental or food allergens, insect exposure
 5. Diagnosis
 a. Clinical signs
 b. Histopathology to rule out vasculitis
 6. Treatment
 a. Corticosteroids
 b. Antihistamines
 c. Avoidance of the inciting cause if one can be identified
- B. Angioedema
 1. Rare in the horse
 2. Type I hypersensitivity
 3. Massive swelling and edema of the head, neck, ventrum
 4. Diagnosis and treatment are the same as for urticaria
- C. Collagenolytic granuloma
 1. The most common nodular skin disease in the horse
 2. Unknown mechanism—may be related to insect exposure
 3. Nonpruritic nodules
 4. Diagnosis: Histopathology
 5. Treatment
 a. Avoid insect exposure
 b. Intralesional corticosteroids
 c. Surgical excision
- D. Sterile nodular panniculitis
 1. Multiple deep nodules that may be painful
 2. May drain hemorrhagic oily exudate
 3. Diagnosis
 a. Cytology
 b. Histopathology
 c. Tissue culture (biopsy for culture)
 4. Treatment: Immunosuppressive therapy with corticosteroids

VIII. Neoplastic causes
- A. Cutaneous papillomatosis (warts)
 1. Caused by a papovavirus
 2. Young horses 1 to 2 years old
 3. Normally around the muzzle
 4. May spontaneously regress
 5. Diagnosis: Histopathology
 6. Treatment: No effective treatment currently
- B. Sarcoid
 1. Most common neoplasm seen in the horse
 2. Locally aggressive neoplasm that does not metastasize
 3. Cause is not completely understood, but the bovine papilloma viruses have been implicated
 4. Occurs at any age
 5. Diagnosis
 a. Histopathology
 b. Treatment:
 (1) Some lesions can transform to more aggressive lesions as a result of trauma, surgery
 (2) Many therapies have been attempted, including laser surgery, cryotherapy, intratumoral chemotherapy and various topicals
 (3) Autogenous vaccines have not been successful
 (4) Aldara (imiquimod)
- C. Squamous cell carcinoma
 1. Ulcerative or proliferative tumor
 2. Solar-induced
 3. Locally invasive and typically slow to metastasize
 4. Treatment
 a. Radical surgical excision
 b. Various radiation or cryotherapy options
- D. Melanocytic tumors
 1. Older gray horses
 2. Many are malignant and will metastasize
 3. Treatment:
 a. Surgical excision
 b. Cryosurgery
 c. Cimetidine
 d. Cutaneous lymphoma

ALOPECIC AND PIGMENTARY DISORDERS

I. Leukoderma
- A. Acquired localized hypopigmentation. Postinflammatory
- B. Vitiligo
 1. Idiopathic hypopigmentation
 2. Thought to be hereditary
 3. Born pigmented, but hypopigmentation begins within 1 to 2 years of life

II. Leukotrichia
- A. Acquired localized loss of hair pigment. Postinflammatory
- B. Spotted leukotrichia. Idiopathic localized to multifocal loss of hair pigment
- C. Reticulated leukotrichia
 1. Young horses

2. Linear crusts on the back between the withers and the tail
3. Can be painful in some cases
4. Permanent condition

III. Anagen defluxion
 A. Generalized alopecia associated with severe illness
 B. Occurs within days to week of incident
 C. Hair will return

IV. Mane and tail dystrophy
 A. Focal or diffuse alopecia of the mane and tail
 B. Typically noted within the Appaloosa breed

Supplemental Reading

Scott DW, Miller WH. *Equine Dermatology.* St Louis, 2003, Saunders.

Knottenbett DC. *Pascoe's Principles and Practice of Equine Dermatology,* 2nd ed., Philadelphia, 2009, Saunders.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

34 CHAPTER

Diagnostic Imaging

Rebecca S. McConnico

CONVENTIONAL RADIOGRAPHY

I. The foot: P3 (distal or 3rd pedal bone)
 A. Two views
 1. Frontal view: Dorsopalmar, dorsoplantar (DP)
 2. Lateral to medial view
 B. Anatomy
 1. P3 has three surfaces
 a. Articular
 b. Parietal (face)
 c. Solar (bearing surface)
 2. Parietal sulcus–dorsopalmar view: Bilateral notches in the lateral cartilages (harbors the dorsal artery of the foot)
 3. Solar canal: Pair of small radiolucent ovals in the middle third of the distal phalanx (DP)
 4. Solar margin: Appearance is highly variable and should not be mistaken for disease
 5. Vascular channels: Size, shape, and number are highly variable
 6. Density of P3: Variable and can change with age and use levels
 7. Width of the distal interphalangeal joint is often uneven during radiography imaging because of the horse shifting weight
 8. Many horses have a notched toe (do not confuse with focal osteomyelitis)
 9. If the solar surface is not cleaned and packed before radiography, a characteristic V shape may appear in the high coronary view (which indicates gas in the sulci) (Figure 34-1)
 C. Abnormalities
 1. Pedal osteitis (Figure 34-2)
 a. Nonspecific inflammation of the DP
 b. Radiographic signs
 (1) Decreased bone density
 (2) Course trabeculation
 (3) Marginal irregularity
 (4) Increased size, shape, and number of vascular channels
 2. Laminitis (Figure 34-3)
 a. Single lateral view is often all that is needed to diagnose distal phalangeal displacement or rotation
 b. Not necessary to use metallic devices for reference points because the coronary band is visible
 c. Microfractures may be visible at the P3 solar tip
 d. Rotation: The distal two thirds of P3 pulls away from the solar laminae, leaving the extensor process in a normal position. Loss of parallel alignment between dorsal hoof wall and dorsal P3
 e. Sinking: Linford method, the width of the soft tissue overlying the dorsal surface of P3
 f. Gas along the inner surface of the hoof wall constitutes evidence of founder
 g. Chronic laminitis: Vascular injury leads to abnormal hoof growth
 h. Prognosis
 (1) Rotation, distal displacement, and laminar gas result in a poor prognosis
 (2) Solar penetration – grave prognosis for soundness
 3. Distal phalangeal fractures
 a. Common causes
 (1) Racing on extensive hard surfaces
 (2) Blunt trauma
 (3) Preexisting foot disease
 (4) Collision with another horse during a race
 b. Most commonly affect the articular surface and usually through the left or right lateral surface; may be due to uneven weight distribution
 c. Clinical signs
 (1) Lameness
 (2) Regional hyperemia
 (3) Excessive heat
 (4) Increased pulses
 d. Standard P3 fracture series
 (1) High coronary (70-degree displacement)
 (2) Right and left frontal obliques
 (3) True lateral
 e. Distal phalangeal fracture types
 (1) Complete extending through the bone in the sagittal or parasagittal plane
 (a) Enter the coffin joint
 (b) More painful
 (2) Solar margin fracture
 (a) Toe fractures
 (b) Indirect result of distal phalangeal rotation subsequent to laminitis
 (c) Marginal sequestrum: Fractures of sequestrum

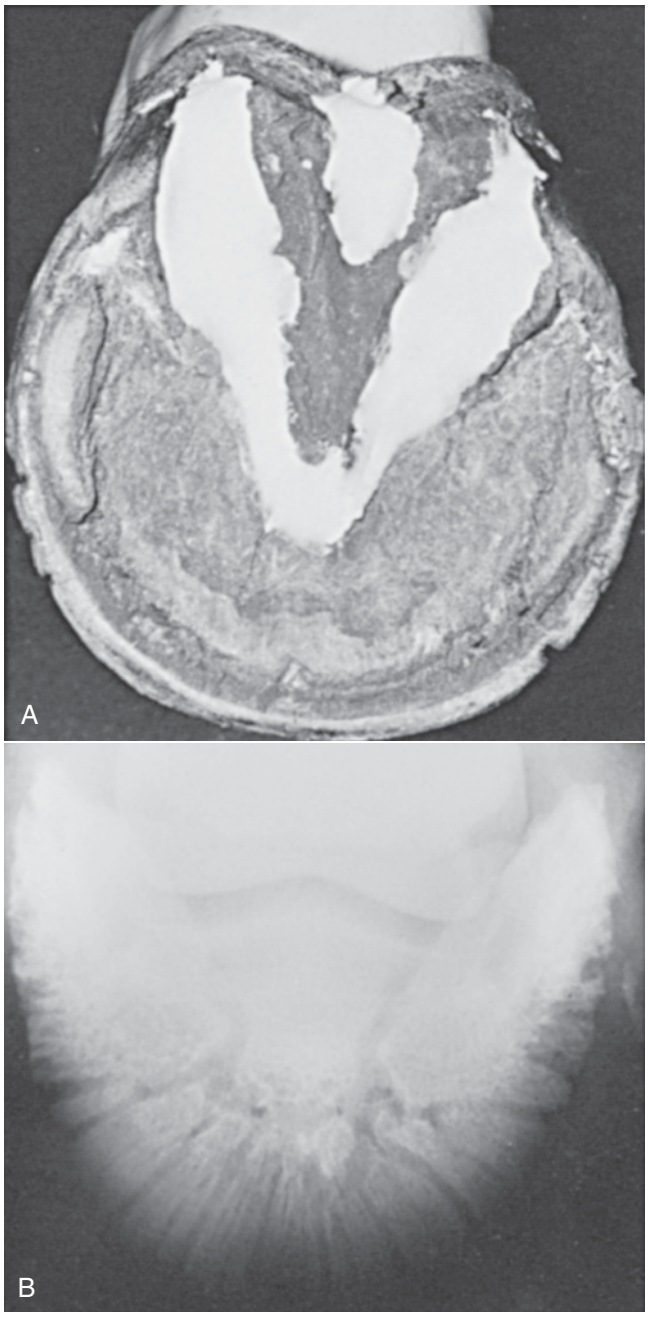


Figure 34-1 **A,** The central and collateral sulci of the foot have been packed with a pliable material of similar radiopacity as the sole (Play-Doh). **B,** Dorsal 65-degree proximal-palmarodistal view of a normal P3 with the sulci packed. Note the good definition of vascular channels without superimposed air artifacts. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology*, 5th ed. Philadelphia, 2007, Saunders.)

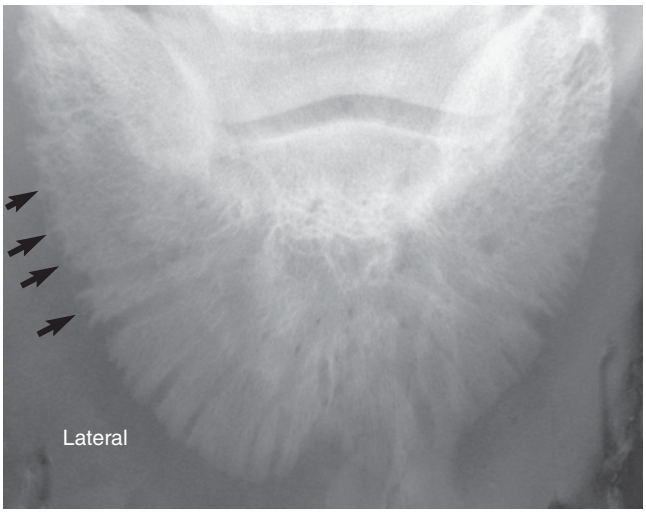


Figure 34-2 Dorsal 65-degree proximal-palmarodistal view of the P3 of a horse with pedal osteitis. Note the irregular margin of the lateral aspect of P3 (*arrows*). (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology*, 5th ed. Philadelphia, 2007, Saunders.)

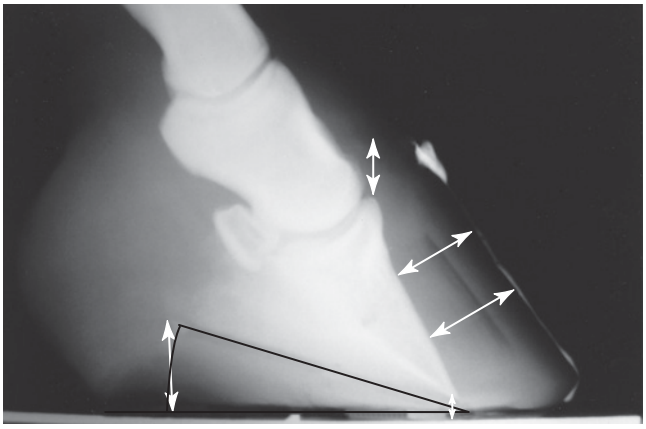


Figure 34-3 Radiograph of a grade III laminitic event. (From Floyd A. *Equine Podiatry.* Philadelphia, 2007, Saunders.)

(3) Wing fractures
(a) Requires oblique views for visualization
(b) Not as painful as articular fractures
(4) Extensor process fractures
(a) Traumatic avulsion
(b) Blunt-force injury
(c) Osteochondritis
(d) Pathologic fracture through bone cyst
(e) Nonunion of an accessory growth center
4. P3 infections
a. Develop secondary to sole abscesses
b. Indicators of P3 infection: Gas, abscessation, drainage, foreign bodies, focal bone loss, infectious sequestration

II. Middle phalangeal bone (P2)
A. Normal anatomic views
1. Focal concavity in the center of the midsaggital ridge: Can be abnormal in horses with navicular disease (radiograph the normal foot for comparison)
2. Gas in the sulcus can mimic fracture
B. Abnormalities
1. Fractures
a. Avulsion of the palmaromedial eminence
(1) Most common in cutting, reining, and barrel horses

(2) Usually involves severe damage of the joint surface
(3) Displaced fractures of both the lateral and medial eminences accompanied by additional breaks
b. Comminuted middle phalangeal fractures are difficult to assess radiographically; computed tomography is better for determining extent of damage
2. Navicular disease: Views
a. True lateral: Evaluates flexor and articular cortices and corticomedullary distinction
b. Two dorsopalmar views (45 and 70 degrees): Evaluate the proximal border of the navicular bone
c. Skyline view: Evaluates the flexor border and corticomedullary distinction

III. Pastern joint (proximal interphalangeal joint)
A. Views: Four full-length views of
1. Long pastern bone
2. Short pastern bones
3. Fetlock joint
4. Pastern joint
5. Coffin joint
B. Abnormalities
1. Narrowing, usually temporary
2. Widening, more common in immature horses because of cartilage
C. Pastern radiography
1. P1 is twice as long as P2
2. Extensor process: Attachment of the lateral and common digital extensor tendons
D. Ringbone
1. Extraarticular bone deposits
2. Joints do not fuse
3. Primary ringbone: Bilateral with no history of previous injury. Possibly heritable
4. Secondary ringbone: Post-traumatic osteoarthritis affecting one or both interphalangeal joints
E. P1 and P2 fractures
1. Proximal physes close between 18 and 30 weeks of age: Should not be confused with fractures
2. Growth plate fractures: Acute, painful; chronic, not painful
3. Most nondisplaced fractures heal with a cast
F. Osteochondritis
1. Most subchondral bone cysts occur in young horses
2. Many disappear spontaneously within 1.5 to 2.5 years
3. Prognosis is usually good
G. Tumors
1. Keratoma: May use ultrasonography for diagnosis
2. Fibroma
H. Pastern arthrodesis

IV. Fetlock joint
A. Views
1. Standard fetlock series
2. Frontal (dorsopalmar), true lateral, lateral and medial obliques
3. Optional flexed lateral
B. Anatomy
1. Forelimb proximal sesamoids are larger and more triangular than those in the hindlimb
2. P1 nutrient foramen is variable in location
C. Abnormalities
1. Fractures
2. Fetlock joint arthritis
a. Joint capsule: Intracapsular swelling
b. Cranial aspect
(1) Variable-shaped osteophytes
(2) Focal surface defects
(3) Periosteal new bone
(4) Soft tissue swelling
c. Palmar-plantar aspect: Flattening, abnormal subchondral bone density and defects corresponding to damaged and defective articular cartilage with bone loss
d. Proximal and distal articular surfaces of sesamoid bones: Periarticular bone deposition
3. Osteochondritis dessicans
a. P1
(1) Hindlimb bilateral lesions are most common; caudal tuberosity is typical
(2) One or more fragments surrounded by new bone
b. MC3 epiphysis
(1) Subtle flattening of subchondral bone
(2) Focal concavities
(3) Cyst-like lesions
c. MC3 sagittal ridge: Small bone fragment
d. Proximal sesamoid bone: Appear fractured with or without displacement

V. Proximal sesamoids
A. Part of the suspensory apparatus
B. Fracture of the sesamoids
1. Apical fractures
2. Body fractures
3. Basilar fractures
4. Sesamoidian avulsion fractures

VI. Metacarpus
A. Standard series: Frontal, true lateral, lateral and medial oblique
B. Abnormalities
1. Splint bone fractures: Distal third of the shaft (do not confuse fracture with nutrient foramen)
2. Canon bone fractures
3. Sequestration: Usually involves outer third of the cortex, most often associated with soft tissue injury
a. Infection through the skin wound
b. Soft tissue swelling
c. Periosteal reaction
d. Bone necrosis secondary to devascularization
e. Fragment of dead bone that detaches from parent bone
4. Osselets

VII. Carpus
A. Standard views
1. Dorsopalmar, lateral, medial oblique, lateral oblique, flexed lateral

2. Supplementary view: Skyline view highlights the cranial edge of distal radius, dorsal edge of distal carpal row

B. Abnormalities: Carpal fractures
1. Occur during racing or race training
2. Clinical signs: Sudden pain and lameness
3. Radiographic features
 a. Sharp fragment margination
 b. Fracture bed in an adjacent bone
 c. Normal surrounding bone density
 d. Absence of osteoarthritis
 e. Localized hot, painful joint swelling
 f. Subacute injury: Characterized by fuzzy margins. Combination of reabsorption of dead bone from the fragment edges
 g. Chronic injuries: Older osteochondral fragments reveal indistinct fragment margination, absent fracture bed, decreased contiguous bone density, osteoarthritis of the affected joint, nonpainful joint swelling
4. Types
 a. Chip (osteochondral fragment)
 (1) Sheared pieces of bone from the upper or lower corners of the carpal bones
 (2) Most commonly chipped
 (a) Radial carpal bone
 (b) Intermediate carpal bone
 b. Corner fractures
 (1) Upper or lower front corner
 (2) More serious injury
 (3) Most common site is distal radius
 c. Slab or biarticulate
 (1) Characterized by entering two adjacent joints
 (2) Most destabilizing
 (3) Most common is third carpal bone
5. Incidence and location
 a. Right more common than left
 b. Affected dorsal carpus and distal radius: Flexed lateral most useful in making the diagnosis
 c. Accessory: Most common in hunter-jumpers and steeplechase horses

VIII. Forelimb: Olecranon fractures
A. Lateral and craniocaudal views
B. Usually enter the humeroulnar joint

IX. Stifle series
A. Lateral and craniocaudal views
B. Anatomy
1. Two joints: Femoropatellar and femorotibial joint
2. Patella is a sesamoid bone attached to the quadriceps femoris
C. Abnormalities
1. Fractured patella: Secondary to a kick or collision with an object
2. Dislocated patella
3. Femoral bone cysts: Common site, the medial femoral condyle, communicates with femoral tibial joint

X. Tarsal disease (hock)
A. Standard series
1. Plantodorsal
2. Lateral
3. Medial oblique
4. Lateral oblique
B. Anatomy
1. Six individual bones: Talus, calcaneus, central, third, fourth, fused first, and second
2. Four major horizontal joints: Tibiotarsal or tarsocrural, proximal intertarsal, distal intertarsal, and tarsometatarsal
3. Four discrete synovial pouches: Tibiotarsal, proximal intertarsal, distal intertarsal, and tarsometatarsal
4. Tibiotarsal and proximal intertarsal joints communicate dorsally
C. Abnormalities
1. Osteoarthritis: Spavin – osteoarthritis of the hock – best projection – plantodorsal and medial oblique – boney proliferation
2. Thoroughpin: Distention of the tarsal synovial sheath

Additional discussion of diagnostic radiography is included in separate system sections.

35 CHAPTER

Endocrine Disorders

Rebecca S. McConnico

EQUINE CUSHING-LIKE SYNDROME (ECD) OR PARS INTERMEDIA DYSFUNCTION (PID)

I. Previously known as
 A. Equine hyperadrenocorticism
 B. Equine diabetes
 C. Equine Cushing disease
 D. Equine cushinoid-like syndrome
II. Role of the hypothalamus
 A. Translator between central nervous system (CNS) and pituitary gland
 B. Equine pars intermedia hyperplasia may be related to hypothalamic dysfunction
III. Pituitary anatomy
 A. Pituitary gland weighs about 1 to 3 g; 2 × 1 cm
 B. Pars intermedia
 1. Secretory control: Tonic inhibition is via dopamine
 2. Other modulators
 a. Serotonin
 b. Adrenergic stimulation
 c. α-Amino butyric acid
 d. γ-Aminobutyric acid (GABA)-ergic
IV. Pathophysiology
 A. Functional adenoma (hypertrophy) or adenomatous hyperplasia of the pituitary pars intermedia associated with a clinical syndrome of hirsutism
 1. Increased β-endorphin
 2. Increased α-melanotropin
 3. Increased endogenous adrenocorticotropic hormone (ACTH) (small amount)
 a. Similar to human and canine pituitary-dependent hyperadrenocorticism (increased ACTH) though not identical
 b. Initial loss of neurotransmitter—dopamine (dopamine is inhibitory)
 B. Gross pathology
 1. Pars intermedia is grossly enlarged
 2. Compression of pars nervosa and the rest of the adenohypophysis as a result of pars intermedia expansion
 3. Adrenal gland hyperplasia (bilateral)
 C. Histopathology
 1. "Abnormal" cells are polyhedral, spindal-shaped, or cylindrical. Usually arranged in columns or rosettes around capillary beds and connective tissue septae
 2. Mitotic index is low
 3. Controversial as to whether this is neoplastic or true hyperplasia
V. Signalment (ECD or PID)
 A. Average age = 19 years (range = 7 to 40 years)
 B. No sex predilection
 C. No breed predilection
 D. Ponies >> horses (not scientifically proven)
VI. Clinical signs of ECD or PID
 A. Chronic or recurrent laminitis
 1. May be secondary to increased cortisol levels (or vice versa)
 2. Sole abscesses—chronic
 3. Chronic increased cortisone levels
 4. May be associated with equine metabolic syndrome (insulin resistance and glucose intolerance)
 B. Polyuria (PU), polydipsia (PD)
 1. Result from destruction of pars nervosa by enlarging pars intermedia leading to decreased antidiuretic hormone (ADH) secretion
 2. Chronic hyperglycemia → osmotic diuresis
 3. Cortisol → increases glomerular filtration rate
 C. Hyperhidrosis: Sweat glands are under β-adrenergic control, catecholamine response
 D. Muscle wasting
 1. Disease aging
 2. Corticosteroid myopathy
 3. Weight loss: Parasitism, chronic infection
 E. Hirsutism (85% of cases) (Figure 35-1)
 1. Most common clinical sign
 2. Thick, long, curly coat; not shed
 3. Heavier than normal winter coat
 4. Slow shedding
 5. Patchy alopecia (usually not a hallmark), shed abnormally
 6. Development of "guard" hairs (chin and jugular furrow)
 7. Differential diagnosis = curly-coated fox-trotter
 F. Additional clinical abnormalities
 1. Narcolepsy
 2. Seizures, ataxia, other neurologic signs
 3. Weight loss
 4. Supraorbital fat pads (redistribution of fat)
 5. Decreased responsiveness to painful stimuli
 6. Increased appetite
 7. Recurrent infections
 8. Sinusitis



Figure 35-1 Horse with pars intermedia dysfunction demonstrating the classic sign of hirsutism: a long, shaggy hair coat that fails to shed in the spring. (From Bertone J. *Equine Geriatric Medicine and Surgery.* St Louis, 2006, Saunders.)

9. Pneumonia
10. Skin infections

VII. Differential diagnosis
- A. PU/PD
 1. Renal disease
 2. Primary diabetes insipidus (DI)
 3. Psychogenic DI
 4. Hyperglycemia secondary to pancreatic destruction
 5. Equine Cushing disease (hyperadrenocorticism)
- B. Hyperhidrosis
 1. Functional pheochromocytosis
 2. Adrenal tumor
- C. Additional concerns (ECD/PID)
 1. Chronic dental problems (no teeth); feed pellets
 2. Severe endoparasitism
 a. Check fecal egg counts for intestinal parasites
 b. Some veterinarians recommend deworming every 8 weeks
 3. Supraorbital swellings
 4. Abnormal fat distribution
 5. Elevated respiratory rate: Chronic infections and opportunistic infections
 6. *Nocardia*, *Coccidioides*, fungal → cell-mediated immunity compromised

VIII. Diagnosis
- A. Minimum database
- B. History and clinical signs
- C. Complete blood cell count
 1. May have slight stress leukogram
 2. Neutrophilia
 3. Lymphopenia
- D. Serum chemistry profile: Usually normal
 1. Alkaline phosphatase is sometimes elevated
 2. Hyperlipemia (fat ponies)
 3. Hyperglycemia
 a. Incidence is variable and occurs in approximately 26% to 85% of patients
 b. Hyperglycemia is most likely due to insulin resistance (see equine metabolic syndrome)
- E. Resting cortisol: Usually normal
 1. Diurnal variation
 a. Higher in the morning (normal horse). The highest level occurs between 8:00 AM and noon; the lowest level occurs in late evening
 b. ECD/PID lose the diurnal variation in cortisol concentration
 c. Fall
 2. Increased
 a. Stress
 b. Exercise
 c. Hypoglycemia
 3. Resting tri-iodothyronine (T_3) and thyroxine (T_4) levels: Normal (not affected by hormonal influence)
- F. Endocrine function testing
 1. Dexamethasone suppression test: Test of choice (40 μg/kg or 2 mg/100): ~20 mg
 a. Overnight test
 (1) Draw a pretest for serum cortisol (heparinized tube)
 (2) Administer dexamethasone intramuscularly (IM)
 (3) Draw blood at noon the next day (19-21 hours post-dosing)
 (4) Excellent screening test
 (5) Interpretation: Normal horse less than 1 μg/dL (or less than 30 nmol/L) cortisol 19 hours after administration
 b. Standard test
 (1) Draw presample at midnight
 (2) Administer dexamethasone at midnight
 (3) Draw blood at 8:00 AM, 12:00 noon, 4:00 PM, and midnight
 c. Limitations of the dexamethasone suppression test
 (1) Normal cortisol level is much higher in the fall; important to interpretation!
 (2) Age
 (3) Gender
 (4) Gestation
 2. Thyroid-releasing hormone (TRH) stimulation test
 a. Poor specificity, although gaining in popularity
 b. May be useful to use in horses with laminitis
 c. 1 mg administered intravenously (IV) after baseline insulin and cortisol is taken
 d. In horses with pituitary adenomas → cortisol and insulin should rise in 15 minutes (cortisol) and 1 hour (insulin) and stay elevated for 90 minutes
 e. TRH may be difficult of obtain
 f. Mechanism is unclear but possibly a paradoxical response of diseased pituitary tissue resulting from alterations in the receptor-adenylate cyclase system
 3. ACTH stimulation test
 a. Dose is 1 unit/kg ACTH gel administered IM or 100 international units synthetic ACTH (cosyntropin) IV

b. Does not adequately distinguish between normal and cushinoid horses
c. Useful test for adrenal exhaustion syndrome
d. Normal response = 2-3 × increase in 4 to 8 hours
e. 4 × increase is extremely variable!

4. Insulin tolerance test: Useful only in hyperglycemic Cushing horses (pancreatic disease)
5. Combined dexamethasone suppression test and ACTH response test: Not useful because does not allow distinguishing normal from Cushing horses
6. Glucose tolerance test/insulin tolerance test
 a. Dose is 0.5 g/kg IV glucose; normal horses return to baseline in ~1.5 hours
 b. PID horses often have poor regulatory mechanisms and are insulin resistant; abnormal (erratic) response
 c. Affected horses: Elevated insulin levels
 d. Elevated insulin levels and hyperglycemia
7. Endogenous ACTH levels
 a. Ponies greater than 27 pg/mL = suggests pituitary adenoma
 b. Horses greater than 50 pg/mL = suggests pituitary adenoma
 c. Sample handling is critical. Collect EDTA plasma, and centrifuge immediately. Transfer plasma to a plastic tube (glass binds ACTH) and freeze. Keep frozen until analyzed

IX. Treatment
 A. Careful management of secondary complications
 B. Euglycemic patients have very good prognosis
 C. Drug therapy
 1. Cyproheptadine—antiserotoninergic activity—(0.25 mg/kg every 24 hours for 4 to 8 weeks)
 a. Serotonin antagonist
 b. 0.25 mg/kg orally (PO) for 1 month
 c. May combine with pergolide
 d. Not as expensive as pergolide
 e. Used to treat
 (1) Equine metabolic syndrome
 (2) Obesity-associated syndrome of mature-onset laminitis
 (3) Peripheral Cushing syndrome
 (4) Pseudo-Cushing syndrome
 (5) Insulin-resistance syndrome
 2. Pergolide (Permex): Dopamine agonist (0.5 mg/day PO)
 a. Dopamine agonist: 0.001 mg/kg/day (0.5 mg/horse) PO
 b. Expensive
 c. May take several weeks to determine whether effective
 d. May increase the dose by 0.25 mg/day up to 0.011 mg/kg/day
 e. Adverse side effects are colic and laminitis. If these occur, decrease the dose
 3. Combination of cyproheptadine and pergolide (cyproheptadine 25 mg/kg/day and pergolide 2 to 3 mg/day)
 4. Bromocriptine: Controversial in horses

X. Omental Cushing syndrome
 A. Insulin refractory state
 B. Prediabetes
 C. Central obesity
 D. Hypothyroidism
 E. Syndrome X

EQUINE METABOLIC SYNDROME

I. Causes
 A. Breed predilection (genetic predisposition)
 1. Pony
 2. Morgan horse
 3. Domesticated Spanish Mustang
 4. Peruvian Paso
 5. Pasa Fino
 6. European Warmblood
 B. Age predilection: 8 to 18 years
 C. No sex predilection

II. Pathogenesis: Insulin refractory state
 A. Glucose intolerance
 1. Peripheral tissue or liver insensitive to insulin
 2. Quantity of insulin released is elevated but inadequate for glucose transport into cells
 3. Following IV or PO glucose load (or a grain meal), resolution of resulting hyperglycemia is delayed
 B. Normal response to glucose load
 1. Insulin release by pancreatic B cells suppresses hepatic glucose production
 2. Stimulation of glucose uptake and utilization by skeletal muscle and adipose tissue
 C. Human insulin resistance
 1. Genetic
 2. Prenatal
 3. Environmental
 4. Risk factors
 a. Obesity
 b. Pregnancy
 c. Smoking
 d. Reduced physical activity

III. Clinical signs
 A. General
 1. Obesity
 2. Generalized: Cresty-necked
 3. Fat rump
 4. “Easy keepers”
 B. Clinical signs suggestive of increased glucocorticoid activity
 1. Abnormal distribution of adipose tissue
 2. Elevated circulating insulin levels
 3. Glucose intolerance
 4. Chronic laminitis
 a. Hoof changes
 b. Dropped sole
 c. Divergent growth lines
 d. Widening of the white line zone
 e. Pedal bone displacement (rotation)
 f. Pedal bone remodeling
 g. Pain, usually mild
 5. Elevated plasma lipids

C. Obese horses with laminitis (impaired glucose tolerance)
 1. Insulin-resistant
 2. Hyperinsulinemic
 3. Aberration in blood flow to the laminae
 4. Endothelial dysfunction
 5. Increased vasospasticity

IV. Diagnosis: Elevated serum insulin with normal to elevated serum glucose concentration

V. Treatment
 A. Management strategies
 1. Dietary change: Feed ration with decreased or low glycemic index
 2. Increase exercise
 B. Prevention of obesity-associated insulin refractory state
 1. Do not feed glycemic or high fat ration
 a. Young growing horses
 b. Mature horses
 2. Feed balanced forage-based diet
 3. Feed appropriate vitamins and minerals
 4. Appropriate exercise for the amount of calories provided
 C. Treatment of obesity-associated insulin refractory state
 1. Do not use thyroid supplementation
 2. Vitamin E supplementation
 3. Supportive care
 4. Dietary management
 5. Exercise: Appropriate for stage of laminitis
 6. Client education!

POSTERIOR PITUITARY DYSFUNCTION

I. DI: Rare in horses
 A. Pathogenesis
 1. Decreased release of ADH from posterior pituitary
 2. Secondary to posterior pituitary destruction
 3. Idiopathic DI
 B. Clinical signs are PU and PD
 C. Differential diagnoses
 1. Renal disease
 2. Psychogenic salt-water eater-drinker syndrome
 3. PID: Equine Cushing disease
 D. Diagnostic evaluation
 1. Clinical pathology: Urine specific gravity (USG) less than 1.010
 2. Water-deprivation testing
 a. Will not concentrate urine if there is DI
 b. Will concentrate urine (USG greater than 1.025) if there is psychogenic PD
 c. If there is no concentration of urine after water deprivation, administer exogenous ADH (40 units of pitressin tannate). If urine concentrates, then the diagnosis is central DI (lack of ADH production)
 E. Treatment: Exogenous ADH if there is central DI

II. Nonfunctional tumors of pars intermedia and posterior pituitary
 A. Necrosis
 B. Lymphoma

ADRENAL DISEASE IN HORSES

I. Adrenal exhaustion syndrome
 A. Adrenal insufficiency
 B. Associated with:
 1. Depression, anorexia
 2. Hyponatremia, hypoglycemia, hypochloremia
 C. Seen in horses just off the track, just back from extensive training, or in those with a history of exogenous glucocorticoid administration

II. Adrenal glands are shock organs in the horse. Adrenal hemorrhage and necrosis are common in cases of severe colic, septicemia, and endotoxemia

III. Prevention and treatment
 A. Minimize stress
 B. Supportive care

THYROID GLAND DYSFUNCTION

I. Uncommon; poorly understood in horses. At birth, total plasma concentration of T_4 and T_3 is 10 to 20 $\times$ greater than in adult horses

II. Primary hypothyroid problems have not been documented in adult horses

III. Neonatal hypothyroidism
 A. Etiology
 1. Hyperplastic thyroid = goiter
 2. Caused by ingestion of excess iodine during pregnancy
 3. Idiopathic hyperplastic goiter has been reported in foals in Western Canada and Northwest United States
 4. No breed or sex predilection
 5. Pathognomonic clinical sign = goiter due to increased thyroid stimulating hormone (TSH) (negative feedback) - although, not always present
 B. Clinical signs
 1. Goiter (Figure 35-2)
 2. Incoordination
 3. Poor suckle response
 4. Hypothermia
 5. Tendon contracture
 6. Incomplete ossification of carpal/tarsal bones
 7. Poor righting reflexes
 C. Diagnosis: 5 international units of TSH in 1 day old foal = 2 $\times$ increase
 D. Treatment: Only effective during critical period of development

IV. Adult hypothyroidism
 A. Cause: Surgical thyroidectomy
 B. Clinical signs include lethargy, poor exercise tolerance, muscular problems, increased sensitivity to cold temperatures, delayed shedding of hair, and a coarse, thickened face
 C. In clinical practice (although there is no scientific documentation) there may be obesity, cresty neck, or chronic laminitis
 D. Diagnosis is difficult, expensive; it is hard to find TRH or TSH, and results are difficult to interpret
 1. Adult hypothyroidism should be characterized by low thyroid hormone concentrations with



Figure 35-2 Goiter in a foal. The dam inadvertently was given a ration that contained too much iodine. (From Reed S, Bayly WM, Sellon DC. *Equine Internal Medicine*, 3rd ed. St Louis, 2010, Saunders.)

an elevated TSH concentration (negative feedback response)
2. A reliable TSH assay is unavailable at this time
3. TRH/TSH stimulation test. Measure thyroid hormone concentrations before and 2 and 4 hours after giving TRH or TSH. A normal response is a twofold increase from baseline levels

V. Causes of *low* circulating thyroid levels in horses
A. Food deprivation
B. Phenylbutazone administration
C. High energy diets
D. Diets high in zinc and copper
E. Glucocorticoid therapy
F. Endophyte infected fescue grass
G. Nonthyroidal illness (sick euthyroid)

PARATHYROID DISEASES OF HORSES

I. Types
A. Primary hyperparathyroidism
B. Secondary hyperparathyroidism
1. Nutritional (fairly common)
2. Renal (rare)
C. Parathyroid-independent hypercalcemia

II. Stimulus for parathyroid hormone (PTH) release is decreased calcium
A. Decreased serum ionized calcium concentration causes a release of PTH from the chief cells of the parathyroid glands
B. Increased PTH results in
1. Increased renal tubular resorption of calcium
2. Increased renal excretion of phosphorus
3. Increased bone resorption
4. Increased production of calcitriol (the active form of vitamin D) by the kidney. Increased calcitriol results in
a. Further increase in bone resorption
b. Increased gut absorption of calcium

III. Primary hyperparathyroidism
A. Uncommon; characterized by elevations in both ionized calcium and PTH concentrations
B. Soft tissue calcification
C. Hypertrophic osteopathy
D. Chronic renal insufficiency may be associated

IV. Nutritional secondary hyperparathyroidism (big head; bran disease)
A. Calcium deficiency relative to excess PO_4
B. Serum calcium and PO_4 concentrations are normal; PTH concentration is increased
C. Urinary PO_4 is elevated (fractional excretion of calcium is decreased; fractional excretion of PO_4 is increased
D. Radiography: Bones of the head and neck show decreased radiopacity
E. Diagnosis is based on diet analysis (Calcium: phosphorus less than 1.5:1), clinical signs of osteodystrophy (big head), bone pain, and enlarged physes, decreased bone opacity on radiographs, normal serum calcium with elevated PTH concentration, fractional clearance of calcium greater than 2.5% and fractional clearance of phosphorus less than 4%

V. Renal secondary hyperparathyroidism
A. Characterized by normal to low ionized calcium concentration, with an elevated PTH concentration. Serum total calcium concentration may be mildly elevated
B. Hypophosphatemia may be associated with oliguria
C. Occurs in association with acute to chronic renal disease

VI. Vitamin D toxicosis
A. Caused by excess ingestion of vitamin D
B. Characterized by hypercalcemia, with low concentration of PTH (a parathyroid independent hypercalcemia). Hyperphosphatemia has been reported in some horses
C. The plant *Cestrum diurnum* (wild jessamine, day cestrum) contains calcitriol-like glycosides which can cause hypercalcemia if ingested

VII. Tumors
A. Characterized by elevated serum ionized and total calcium concentrations, with low PTH concentration (parathyroid-independent hypercalcemia)
B. The hypercalcemia associated with tumors has been previously called *pseudohyperparathyroidism*, but this term is misleading as the PTH concentration is low, not elevated
C. Hypercalcemia has been noted in association with lymphoma, squamous cell carcinoma (gastric and vulvar), and mesothelioma

EQUINE ANHIDROSIS

I. Introduction
A. Also known as
1. Dry coat
2. Nonsweating
B. Definition: Inability to sweat effectively in response to appropriate stimuli
C. Common cause of exercise intolerance in horses in the South (Louisiana, Mississippi, Alabama, Florida) and worldwide

D. Earliest recorded cases in British thoroughbreds imported to tropical colonies
E. Occurs more commonly in
1. Long-time inhabitants of a hot climate
2. Horses in training
3. May be higher in horses fed high-protein diets
4. No predilection for coat color, gender, age, or breed
F. Thermoregulation
1. Respiratory tract = 15% to 25% of heat loss
2. Sweat evaporation = ~ 65%
3. Factors influencing heat dissipation rate
a. Rate of air movement across the skin
b. Humidity in environment: The higher the humidity, the less heat is dissipated
c. Large body-volume to skin-surface ratio
d. Cardiac output competition between skin and muscle circulation
e. Inhibition of nitric oxide synthase
G. Equine sweat glands
1. β2 adrenergic receptor stimulation
2. Humoral control causes adrenergic agonists release from the adrenal medulla
3. Nervous control stimulates autonomic adrenergic nerves

II. Pathophysiology: Potential mechanisms
A. CNS disorder
B. Adrenal dysfunction
C. Sweat gland abnormalities
D. Progressive reduction in response of sweat glands to catecholamines
E. Circulating increase of epinephrine in anhidrotic horses
F. Thyroid hormone deficiency
G. Electrolyte imbalances
H. Hormonal or metabolic imbalance may play a role both in the onset and secondary signs

III. Clinical signs
A. Inability to "cool-out" within 30 minutes after exercise
B. Predominant sign = *tachypnea*
C. Hyperthermia
D. Tachycardia
E. No sweating or minimal sweating upon exercise
F. Long-standing cases
G. Dry, flaky skin
H. Partial nonsweater

IV. Diagnosis
A. Clinical signs and exercise performance
B. Tachypnea and inability to thermoregulate after exercise
C. Intradermal sweat test
D. Test on the neck using dilution of terbutaline (b2), salbutamol (b2), or epinephrine (a and b) in decreasing dilutions

V. Treatment
A. All anecdotal
B. Management changes: Environment control
1. Air-conditioned stall
2. Keep the barn cooler
3. Exercise horse only during the cool part of the day
C. Medical therapy
1. Electrolyte supplementation
2. 60 g Lite salt (sodium +) or pack of Enterolyte
3. One AC (Phoenix, AZ) Contains tyrosine (may resensitize b2 receptors), ascorbic acid, niacin, and cobalt
4. Methyldopa decreases sympathetic drive, 3000 mg once daily
5. Thyroid supplementation
6. Clenbuterol: Cools the horse by increasing circulation and direct stimulation of sweat gland
7. Acupuncture
8. Rubella virus immunotherapy
D. Combination of management and medical therapy.

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St. Louis, 2004, Saunders.
Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St. Louis, 2009, Saunders.
Smith BP. Large *Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

36 CHAPTER

Gastrointestinal Diseases

Rebecca S. McConnico

OVERVIEW

I. Signalment and history
 A. Common occurrences
 B. Increased likelihood of certain types of colic based on history and signalment
 1. Age
 a. Foals
 (1) Meconium impaction
 (2) Uroabdomen
 (3) Enterocolitis (gram-negative septicemia, *Clostridium difficile*, *Rotavirus*)
 (4) Ileus associated with hypoxic ischemic encephalopathy
 (5) Intestinal incarceration in hernia (umbilical, inguinal)
 (6) Congenital defects (atresia ani/coli, colonic aganglionosis)
 b. Weanlings: Ascarid impaction or diarrhea
 c. Young adults and performance horses: Gastric-colonic ulcers
 d. Mature and older horses
 (1) Strangulating lipoma
 (2) Epiploic foramen entrapment (cribbing may also increase risk)
 (3) Neoplasia (except lymphoma, which is more common in younger animals)
 2. Sex and reproductive status
 a. Stallion (intact male): Inguinal hernia/ incarceration in inguinal rings
 b. Mare
 (1) Pregnant: Uterine torsion
 (2) Postpartum
 (a) Mesocolon (small colon mesentery) avulsion
 (b) Rectal prolapse
 (c) Colon torsion
 (d) Uterine artery rupture
 (e) Retained placenta
 (f) Rectovaginal tear
 (g) Bruised small colon (traumatic partitution)
 3. Breed
 a. Arabians
 b. Standardbreds and draft breeds (colts, inguinal hernia)
 c. Paints (overo x overo foals, colonic aganglionosis)
 4. Diet
 a. High-grain diets (gastric ulcers)
 b. Coastal hay (recent introduction, ileal impaction)
 c. Alfalfa hay (long-term use, enteroliths)
 5. Environment and geography
 a. Florida, sandy pastures (sand colic)
 b. California, Texas (enteroliths)
II. General risk factors
 A. Change in routine
 1. Diet change
 2. Reduced water intake
 3. Change in exercise schedule
 B. Certain types of feed
 1. Coastal hay (ileal impaction)
 2. Alfalfa hay (enteroliths)
 C. Poor dentition (impaction)
 D. Inadequate parasite control
 E. General anesthesia (cecal impaction)

GASTROINTESTINAL (GI) DYSFUNCTION (COLIC): NUMBER ONE KILLER OF HORSES!

I. Definition
 A. Clinical signs associated with abdominal pain
 B. Encompasses a wide variety of disease processes
 1. Includes GI and extraintestinal causes of pain
 2. The gut is the shock organ of the horse
II. Signs of colic
 A. Poor appetite or loss of appetite
 B. Posturing to urinate, stretching out ("camping out")
 C. Looking at abdomen ("flank-watching")
 D. Kicking at abdomen
 E. Pawing
 F. Abnormally distended abdomen
 G. Getting up and down frequently
 H. Rolling
 I. Tachycardia
 1. Mild increases associated with nonstrangulating large intestinal disease
 2. Tachypnea
 J. Mucous membrane color
 1. Pale with pain, hemorrhage, or vascular compromise-strangulation
 2. Injected with toxemia, infection, or other inflammation
 K. Abdominal distention

L. GI sounds
1. Vary from hypermotile to absent, depending on disease process
2. Gas ping may be ausculted over cecum

III. Causes
A. Mucosal injury or inflammation
1. Ulceration
2. Infiltration
B. Serosal injury or inflammation
1. Adhesions
2. Peritonitis

IV. GI causes
A. Obstruction
B. Inflammation
1. Inflammatory bowel disease
2. Because mucosa is most metabolically active, enteritis usually has most profound effect on mucosal layer
3. ↓ absorption
4. ↑ secretion
5. Diarrhea and reflux

V. Non-GI causes of "colic"
A. Peritonitis
B. Septic peritonitis
C. Uroabdomen
D. Hemoabdomen
E. Renal disease
F. Acute renal failure
G. Hydronephrosis
H. Urinary tract obstruction
I. Pleuritis
J. Pericarditis
K. Hepatic disease
1. Pyrrolizidine alkaloid toxicosis
2. Hepatic lipidosis
L. Cholangiohepatitis
M. Neoplasia
N. Reproductive disease or trauma
1. Uterine torsion
2. Uterine artery rupture
3. Endometritis
O. Encephalitides

VI. Medical management of colic
A. Narcotics
1. Butorphanol: Good visceral analgesia
a. Opiate
b. Minimal effects on motility
c. May cause mild ataxia/restlessness
d. Use in combination with sedative
2. Pentazocine, meperidine, morphine
a. Associated with adverse effects
b. *Not* recommended
B. α2-agonist: Xylazine or detomidine
1. Analgesia at higher doses
2. Decreases large intestine motility (dose dependent)
C. Nonsteroidal antiinflammatory drugs (NSAIDs)
1. Flunixen
2. Phenylbutazone
3. Ketoprofen
4. Dipyrone
5. Cyclo-oxygenase-1 (COX-1)-sparing NSAID soon to be available for colic treatment

OTHER GI DISORDERS

I. Equine Gastric Ulcer Syndrome (EGUS)
A. Erosion of gastric mucosal lining; Prolonged exposure to the acid
B. Variable degrees of severity
1. Inflamed: No ulceration to widespread erosion and bleeding (in extreme circumstances the condition develops to such an extent that perforation of the stomach can occur; fatalities can occur in foals)
2. Four-point scoring system has been developed; grades 2 or above are considered clinically significant
C. Clinical signs
1. Partial anorexia
2. With or without bruxism
3. Colic
4. Poor performance
5. Poor haircoat
6. Weight loss
D. Diagnosis
1. Complete blood cell count: Normal
2. Serum chemistries: Within normal limits
3. Fecal: Negative
4. Rectal: Empty GI tract
5. Gastroscopy
E. Treatment
1. Minimize stress
2. Turn out to pasture with a buddy horse
3. Dietary management
a. Low carbohydrate
b. Controversy regarding roughage
c. Good quality hay
d. Alfalfa
e. No stems
4. Medications
a. Histamine-2 antagonists
(1) Cimetidine: Use until blood levels of omeprazole are achieved
(2) Ranitidine
b. Proton pump inhibitor: Omeprazole
c. Protectants: May be useful in foals

II. Intraluminal obstruction
A. Pain results from mucosal irritation and or gas-fluid accumulation orad to obstruction
B. Impaction
1. Feed or foreign body (enterolith, fecalith)
2. Common sites
a. Ileum
b. Ileocecal junction
c. Cecum
d. Large colon-pelvic flexure
e. Small colon

III. Extraluminal obstruction: Nonstrangulating obstruction
A. Pain results from mesenteric tension and or gas-fluid buildup orad to obstruction
B. Colon displacement
1. Nephrosplenic entrapment-left dorsal displacement (Figure 36-1)
2. Right dorsal displacement (Figure 36-2)
C. Early small intestinal entrapment

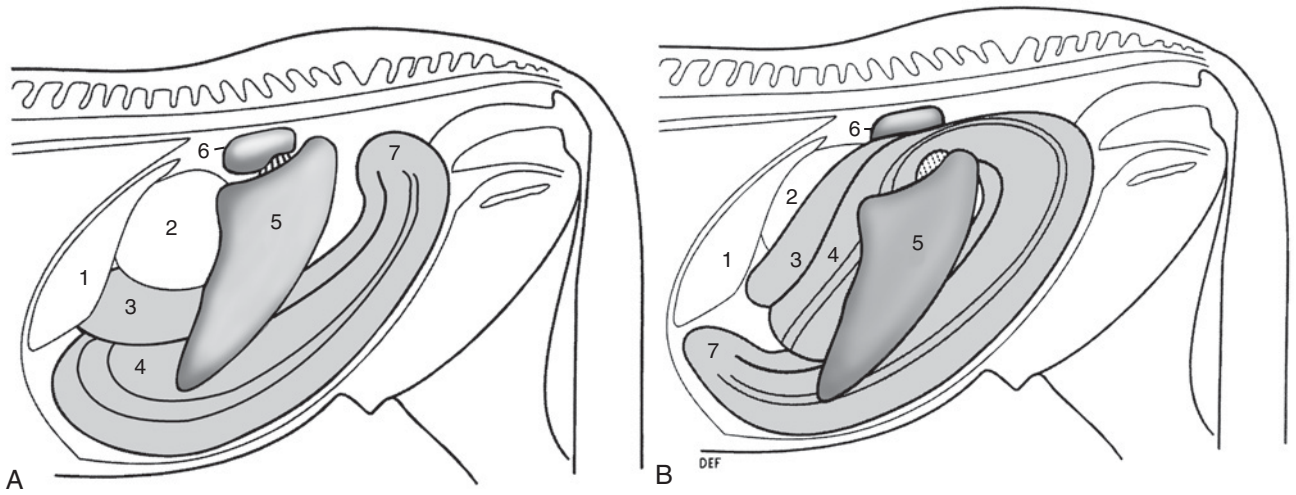


Figure 36-1 *A,* Left lateral view of abdomen of a normal horse. *B,* Left dorsal displacement of the left colon, left lateral view. The left ventral and dorsal colon are displaced lateral and dorsal to the spleen and occupy the renosplenic space. 1 = liver, 2 = stomach, 3 = left dorsal colon, 4 = left ventral colon, 5 = spleen, 6 = left kidney and renosplenic ligament, 7 = pelvic flexure. (With permission from Johnston JK, Freeman DE: Diseases and surgery of the large colon, *Vet Clin North Am Equine Pract* 13:317, 1997.)

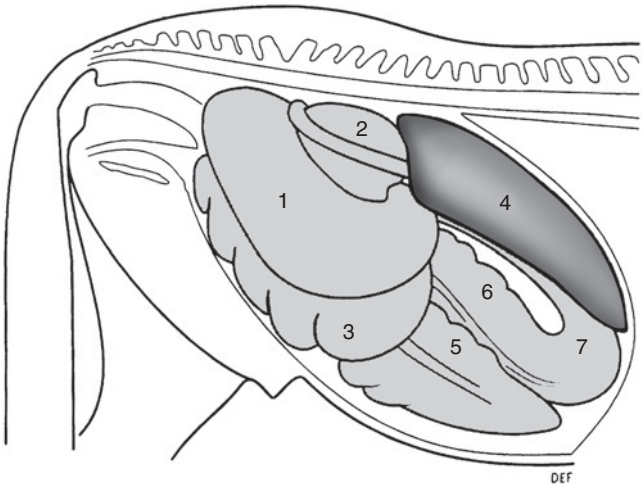


Figure 36-2 Right dorsal displacement of the colon, right lateral view. The colon has passed lateral to the cecum, the pelvic flexure is displaced cranially, and the sternal and diaphragmatic flexures are displaced caudally. 1 = right dorsal colon, 2 = base of cecum, 3 = right ventral colon, 4 = liver, 5 = cecum, 6 = left ventral colon, 7 = pelvic flexure. (With permission from Johnston JK, Freeman DE: Diseases and surgery of the large colon, *Vet Clin North Am Equine Pract* 13:317, 1997.)

IV. Inflammation
 A. All GI disease results in inflammation
 B. Sources of inflammation
 1. Parasitism
 2. Enterotoxins
 3. Reperfusion injury
 C. Infiltrative diseases
 1. Lymphocytic-plasmocytic enteritis-colitis
 2. Eosinophilic enteritis-colitis
 a. Focal plaques (emerging recognition)
 b. Diffuse infiltration
 3. Granulomatous enteritis-colitis

V. Infection
 A. Usually seen as diarrhea or reflux with associated signs of colic
 B. Fever, leukopenia may also be present
 C. Major pathogens
 1. *Salmonella* spp.
 2. *Clostridium difficile*
 3. *Clostridium perfringens* (types A and C)
 4. *Neorickettsia risticii* (Potomac horse fever)
 5. Rotavirus

VI. Ulceration
 A. Loss of mucosal lining
 B. Gastric ulcers
 1. Excessive exposure of mucosa to stomach acid (pH < 4.0) and loss of normal buffering
 2. Lesions most commonly in squamous portion at margo plicatus
 3. Associated with feed deprivation, NSAIDs, low roughage diets, stress, enterocolitis (in foals)
 4. Signs include loss of appetite, bruxism, and mild colic
 C. Colonic ulcers (right dorsal colitis)
 1. Associated with NSAID use
 2. Signs include fever, colic, and diarrhea

VII. Thromboembolism
 A. Pain results from ischemic necrosis
 B. *Strongylus vulgaris* (large strongyles)
 1. Larvae migrate to cranial mesenteric artery
 2. Chronic inflammation and buildup of larvae result in occlusion of artery and loss of blood supply to intestine
 3. Uncommon since introduction of ivermectin
 C. Systemic inflammatory response syndrome. Disseminated intravascular coagulation can result in emboli formation in smaller mesenteric arteries

VIII. Neoplasia
 A. Often presents as weight loss despite a good appetite

B. Lymphosarcoma
 1. Most common intestinal neoplasia
 2. Small intestinal infiltration
 3. More often affects younger horses
C. Gastric squamous cell carcinoma: Primary or metastatic

IX. Equine esophageal obstruction: Choke
A. General information
 1. Occurs occasionally
 2. Causes sudden discomfort and anxiety
 3. Caused by a bolus or wad of feed material that gets lodged in the esophagus
 4. Often a result of an overzealous appetite
 5. Beet pulp and incompletely chewed hay are often involved
 6. Any feed can cause a problem
B. Clinical signs (Figure 36-3)
 1. Horse stretches neck out
 2. Makes a gasping sound
 3. Saliva pours from the horse's nose, may be green tinged
 4. Some horses may lie down and appear colicky
 5. Horses who have choked in the past or those that have suffered damage to their throats or necks may be repeatedly susceptible to this problem
 6. For most horses, the obstruction passes uneventfully in a few minutes



Figure 36-3 Nasal regurgitation of feed due to esophageal obstruction. (Courtesy of Dr. Michelle H. Barton, University of Georgia.)

C. Treatment
 1. Walking the horse
 2. Tranquilize (α-2 agonists xylazine or detomidine): Relaxes horse and lowers head so horse will not aspirate
 3. Passage of nasogastric tube to gently force the blockage into the stomach
 4. May require systemic antimicrobial therapy for aspiration pneumonia

37 CHAPTER

Infectious Diseases

Rebecca S. McConnico

BLOOD-BORNE AGENTS

I. Equine infectious anemia (EIA)
 A. EIA is caused by a virus classified in the lentivirus genus of the Retroviridae family
 B. Once infected with this virus, a horse remains infected for life
 C. Acute infection is associated with fever and lethargy
 D. Some horses will exhibit anemia and thrombocytopenia
 E. Most horses recover from this initial febrile episode but may undergo recurring febrile episodes associated with periodic emergence of novel antigenic variants of the virus
 F. In some horses these episodes become more severe and the horse develops classic clinical signs of EIA:
 1. Weight loss
 2. Ventral edema
 3. Fever
 4. Lethargy
 5. Anemia
 6. Thrombocytopenia
 7. Hyperglobulinemia
 G. In most horses, however, the febrile episodes become less frequent and less severe and the horse becomes an inapparent carrier of the virus. Inapparent carriers are normal on physical examination but often have subtle clinicopathological alterations suggestive of ongoing viral activity:
 1. Increased serum globulin concentrations
 2. Decreased albumin:globulin ratio
 3. Intermittent thrombocytopenia or mild anemia
 H. EIA transmission
 1. EIA virus is most commonly transmitted by the intermittent feeding of hematophagous insects, especially biting flies of the genus *Tabanus* (horseflies) or *Chrysops* (deerflies)
 2. Flies are strictly mechanical vectors, and virus does not live long outside the horse
 3. Mosquitoes are *unlikely* to transmit EIA virus for the following reasons:
 a. Mosquitoes do not elicit a painful bite to a horse; thus, feeding pattern is not interrupted
 b. Mosquito saliva adversely affects EIA virus viability
 c. The mosquito's mouth parts are not large enough to contain an infective dose of EIA virus
 d. For transmission to occur, a fly must begin a blood meal on an infected horse, be interrupted, and immediately resume feeding on an uninfected horse
 e. EIA virus may also be transmitted transplacentally, especially if a pregnant mare experiences febrile episodes during gestation
 f. Transmission via ingestion of colostrum or milk from an infected mare is possible but not likely
 g. Venereal transmission is rare
 h. Iatrogenic transmission may occur through the use of shared needles for injections or use of improperly sterilized surgical instruments or other devices that contact equine blood
I. Prevention of EIA
 1. All horses on a farm should be tested at least yearly for the presence of antibodies to EIA virus
 2. Presence of antibodies indicates that a horse is infected and will remain infected for life
 3. EIA virus–positive horses should be permanently quarantined or euthanized. All new arrivals to a farm should be recently EIA virus–negative before arrival on the farm
 4. Farm management practices should attempt to minimize fly populations through appropriate trash and manure disposal and judicious use of chemical or nonchemical insect control programs
 5. Horsefly bites are usually most numerous during daylight hours in wooded areas. Pasture turnout schedules should take these facts into consideration
 6. Horse owners and veterinarians should strictly adhere to the "one needle, one horse" rule. All instruments that come into contact with equine blood should be thoroughly disinfected before use on another horse
 7. Horse owners and veterinarians should encourage organizers of equestrian events to require proof of a negative EIA test for all horses before participation in those events

II. Equine piroplasmosis (babesiosis)
 A. Caused by one of two species of hemoprotozoal parasites: *Babesia caballi* or *Babesia equi*
 B. Intraerythrocytic parasites transmitted primarily by tick vectors
 C. Within 1 to 4 weeks of exposure previously unexposed horses develop signs of
 1. Fever
 2. Depression
 3. Dyspnea
 4. Pale or icteric mucous membranes
 5. Ecchymoses of the nictitating membrane
 6. Constipation
 7. Colic
 8. Dependent edema
 D. Massive infection results in classic signs of intravascular hemolysis:
 1. Icterus
 2. Hemoglobinemia
 3. Anemia
 4. Hemoglobinuria
 5. Hyperbilirubinemia
 E. Clinical signs in horses infected with *B. caballi* last a few days to a few weeks and mortality is low
 F. Most horses spontaneously clear the organism after 12 to 42 months of infection
 G. Infection with *B. equi* is more severe, and horses may die within 24 to 48 hours of the onset of clinical signs
 H. Infection is usually lifelong unless the horse is treated
 I. In endemic areas, it is desirable to suppress clinical signs of disease without eliminating the organism from the horse
 J. As with some other protozoal infections, effective immunity depends on continual exposure to the organism (premunity)
 K. Imidocarb dipropionate or buparvaquone is effective for treatment of clinical signs of babesiosis in horses
 L. *Babesia caballi* infections are easier to eliminate than are *B. equi* infections

III. Equine granulocytic ehrlichiosis
 A. Caused by *Ehrlichia equi*, a rickettsial organism that resides in equine neutrophils and eosinophils
 B. Clinical signs
 1. Fever
 2. Anorexia
 3. Depression
 4. Petechia and ecchymoses
 5. Icterus
 6. Ventral edema
 7. Ataxia that lasts 3 to 16 days
 C. Infected horses are usually:
 1. Thrombocytopenic
 2. Leukopenic and anemic
 3. Clinical signs are most severe in adult horses and foals may experience only a mild fever
 D. Diagnosis and treatment
 1. During acute stages of the infection, granular inclusion bodies may be seen in the cytoplasm of neutrophils and eosinophils on blood smears routinely stained with a Wright's-Giemsa type stain
 2. These inclusions are pleomorphic, blue-gray to dark blue spoke-wheel shapes representing a cluster of coccobacillary organisms within cytoplasmic membrane-bound vesicles
 3. A fluorescent antibody test is available for detection of antibody to the organism
 4. A fourfold change in acute and convalescent titers is considered diagnostic of infection
 5. Mortality is rare, and most untreated horses recover over a period of 2 weeks
 6. Recovery may be hastened by treatment with intravenous (IV) oxytetracycline at 7 mg/kg once or twice daily for up to 7 days

NEUROLOGIC DISORDERS

I. Equine protozoal myelitis (EPM)
 A. Definition: A debilitating neurologic disease of horses that can affect the brain, brainstem, spinal cord, or any combination of these three areas of the central nervous system (CNS)
 B. Clinical signs may suggest focal or multifocal disease, which means that the disease may affect a very small (focal) part of the CNS or many parts of the CNS (multifocal)
 C. The disease may present itself with a variety of different clinical signs, dependent on the location of the damage caused by the organism within the CNS. No vaccine is currently available
 D. Life cycle
 1. Causative organism: Although EPM has been recognized since the 1970s, it was not until 1991 that the organism (protozoan parasite) was cultured from a horse and given the name *Sarcocystis neurona*
 2. The horse is a dead-end aberrant host, as infectious forms of the parasite are not passed from horse to horse or from horse to the definitive or true intermediate hosts
 3. Recent investigation indicates that opossum feces (definitive host) are the source of the infection for horses, although other sources include several other mammalian species, including cats, skunk, raccoon, and others
 4. Opossums acquire the infection by eating infected birds (intermediate hosts)
 5. Most infections come from contaminated pasture, hay, grain, and water with opossum feces. Contamination of feed and water with opossum feces may occur indirectly through other mechanisms such as birds and insects
 6. Control of the parasite to prevent infection of horses will be a daunting task because of the wide distribution of definitive and intermediate hosts in the environment of horses. Relocation of opossums away from horses, water, bedding, and feed storage environments may be beneficial to reduce exposure
 E. Occurrence
 1. EPM occurs in much of North America
 2. Surveys conducted have revealed that

approximately 50% to 80% of horses have been exposed to this parasite
3. A positive serum test indicates exposure to the parasite, not necessarily the presence of disease
4. In the studies that looked at the distribution of seropositive cases geographically, it was found that climatic factors may affect exposure rates; that is, an increase of freezing days was associated with a decrease in numbers of horses exposed to the parasite. A similar effect of very hot environments may also decrease the survival of the infective stages of the protozoan parasites and lessen exposure to horses. EPM appears to have a sporadic distribution, although outbreaks have been reported

F. Clinical signs
1. A progressive disease which if not treated may eventually lead to death
2. Any horse that is demonstrating neurologic abnormalities may have EPM
3. The clinical signs depend on the location of the organism within the CNS. EPM can affect a horse of any age, breed, or sex
4. Clinical signs may be triggered or worsened by physiologic stress or the administration of corticosteroids
5. Clinical signs of the disease:
 a. Weakness
 b. Malposition of a limb
 c. Muscle atrophy
 d. Spinal ataxia or "wobbling"
 e. Head tilt with asymmetry of the face (eyelid, ear, lip)
 f. Severely affected horses may be down and unable to rise
 g. Lameness not traceable to orthopedic disease or any combination of the above signs may occur in early or less severe infections
 h. Other unusual signs may occur
6. Typical case
 a. Affected horses are bright and alert with a normal appetite
 b. Some horses are dysphagic (unable to eat) and may act as if they are choked, with feed material coming from their nose
 c. Hematologic and biochemical blood values are usually in the normal range
 d. Sometimes a horse may have more than one disease, for example, both EPM and cervical stenotic myelopathy ("wobbler")

G. Diagnosis
1. Based on clinical signs and on testing of the horse's cerebrospinal fluid (CSF)
2. A positive serum test cannot be used to make a diagnosis but simply indicates exposure to the parasite, not necessarily the presence of the disease
3. CSF testing is now believed to be the most useful test to assist in the diagnosis of this disease in the live horse
4. The western blot test of CSF detects antibodies that the horse has formed against the parasite. The presence of these antibodies in the CSF of horses with neurologic signs usually indicates active disease. However, if blood contaminates the CSF sample, a false-positive test is a likely result. Positive CSF tests among horses without neurologic signs have occurred; however, the significance of these findings has not been determined. If the test is negative, and the horse is exhibiting clinical signs, the horse may still have the disease. Acupuncture is not recognized as an accurate diagnostic test

H. Therapy
1. Treatment of horses with EPM is expensive
2. The average range of treatment is 90 to 120 days and may exceed 6 months in some instances
3. The appropriate length of treatment and the method to determine adequate treatment duration are unknown
4. The current approved approaches to treatment:
 a. Ponazuril (Marquis, Bayer Pharmaceutical) 5 mg/kg every 24 hours × 28 days
 b. Nitazoxinide (Navigator, Idexx Pharmaceuticals), 25 mg/kg days 1 through 5, then 50 mg/kg days 6 through 28
5. Frequent, periodic, veterinary neurologic examinations during the treatment period. Discontinuation of therapy may be based on administration of medications 30 days beyond the plateau of clinical improvement. An alternative approach to determining discontinuing of therapy is disappearance of antibody to the protozoa from the CSF. Suboptimal dosing of intermittent therapy has no proven efficacy
6. Adverse side effects of therapy may include the following:
 a. Anemia
 b. Abortion
 c. Diarrhea
 d. Low white blood cell count
7. Medications for treatment of EPM inhibit folic acid metabolism. Supplementation with folic acid (40 mg per os [PO], once a day) may help prevent adverse side effects. Folic acid should not be administered at the same time as the antimicrobial drugs
8. In cases with severe neurologic signs, nonsteroidal antiinflammatory treatment medications (NSAIDs) and dimethyl sulfoxide may be added to the treatment regimen. Long-term therapy with NSAID agents should include cyclo-oxygenase-1 (COX-1)-sparing drugs such as fericoxib
9. Vitamin E; 6,000 TO 10,000 units daily PO is recommended as an antioxidant for the duration of therapy

I. Prognosis: Early detection and therapy increase the chance of successful treatment, which is highly variable; many treated horses return to their original level of function; however, some may not respond completely. It is also estimated that approximately 10%

of the cases relapse after treatment is discontinued. Some horses are currently on medication indefinitely

II. West Nile virus
 A. First came to the United States main continent in August 1999
 B. Index cases reported in human and horse
 C. Endemic in Africa and Asia
 D. Over-wintered
 E. Clinical signs
 1. Flulike signs with onset of neurologic disease
 2. Fever
 3. Central neurologic disease
 4. Lethargy
 5. Cortical brain disease: blindness
 6. Seizures
 7. Death
 F. Differentials for encephalitis
 1. Rabies
 2. Eastern equine encephalitis (EEE)
 3. Western equine encephalitis (WEE)
 4. California
 5. Protozoal
 G. Identified in:
 1. 19 species of birds
 2. Small rodents
 3. Horses (1999-2000)
 4. Humans

III. EEE
 A. Recurs in Louisiana annually and has been isolated from, or antibodies to EEE virus have been found in, naturally infected wild and domestic birds with clinical signs of CNS involvement
 B. Transmission is via mosquitoes. *Culiseta melanura* is the principal endemic vector
 1. Wild birds, primarily passerines, serve as the primary amplifying host
 2. Epizootics begin in swamps and move locally outward through viremic birds
 3. Humans and equines are dead-end hosts
 C. Vaccine efficacy can be variable. Vaccinating every 6 months might *not* be enough
 D. Dependent on climatic changes and vector populations
 E. Clinical signs
 1. Biphasic febrile reaction
 2. Outcome can be fatal, or the animals may recover with or without CNS sequelae
 3. Most common signs of illness include depression, fever above 103° F, ataxia, paralysis, anorexia, stupor, irregular gait, grinding of teeth, incoordination, circling, staggering, recumbency, and hyperexcitability

IV. Rabies
 A. Rabies is a highly fatal, contagious disease that affects the CNS
 B. Vectors
 1. Domestic dogs and cats
 2. Skunks
 3. Foxes
 4. Raccoons
 5. Bats
 C. Horses become infected most likely from bite of an infected animal
 D. Clinical signs
 1. Depression
 2. Incoordination
 3. Ataxia
 4. Colic
 5. Fever
 6. Loss of appetite
 7. Muscle spasms of the third eyelid
 8. Blindness
 9. Urinary incontinence
 10. Restlessness
 11. No treatment and highly fatal
 E. Diagnosis: Clinical signs of progressive central neurologic disease that cannot be explained
 F. Prevention: Vaccination

V. Tetanus
 A. A highly fatal infectious disease of domestic animals
 B. Worldwide occurrence
 C. Causative organism: *Clostridium tetani*
 1. Anaerobic spore-forming organism
 2. Normal inhabitant of the gastrointestinal (GI) tract of domestic animals, especially the horse
 D. Sporadic occurrence due to highly effective vaccine availability
 E. Horse is very sensitive to the neurotoxin
 F. Mode of infection: Deep puncture wound, especially from contamination of hoof and castration sites
 G. Spores
 1. Can remain viable in tissues for months
 2. Bacteria can produce toxin in 4 to 8 hours
 H. Three exotoxins are identified
 1. Tetanolysin increases local tissue necrosis
 2. Tetanospasmin ascends via axons of peripheral neurons, binds irreversibly to inhibitory interneurons, and blocks the release of neurotransmitters glycine and γ-amino butyric acid
 3. Nonspasmogenic toxin: Causes peripheral nervous system paralysis
 I. History includes lack of vaccination
 J. Clinical signs
 1. Initial stiffness of gait
 2. Reluctance to lower the head to the ground or eat; progression over 24 to 48 hours
 3. Rigid extension of the tail and neck
 4. Anxious facial expression (sardonic grin)
 5. Erect ears
 6. Nostril flaring
 7. Widely open eyes
 8. Dysphagia (with sialosis)
 9. Sympathetic nervous stimulation may cause colic
 10. Signs are exaggerated by stimuli
 11. Globe retraction and prolapse of the third eyelid
 12. Dyspnea
 13. Impaction colic and pollakiuria
 K. Associated severe clinical signs
 1. Recumbency, opisthotonis, recumbency
 2. Tendon rupture

3. Vertebral or long bone fractures
4. Severe rhabdomyolysis
5. Death resulting from prolonged tetany of the respiratory muscles

L. Diagnosis
1. Clinical signs of exclusion of other disease processes
2. Differential diagnosis includes rabies, laminitis, exertional rhabdomyolysis, and hypocalcemia

M. Treatment
1. Supportive care
2. Large doses of tetanus antitoxin (minimum of 5,000 to 10,000 international units)
3. Tetanus toxoid intramuscularly at separate locations
4. Large doses of Penicillin 50,000 international units/kg of penicillin
5. House horse in quiet, dark stall area with good footing
6. Muscle-relaxing agents may be administered (e.g., phenothiazine derivative tranquilizers)

N. Prognosis: Guarded and can be poor to grave. Severely infected horses will require intensive nursing care. Clinical improvement is slow, and recovery requires up to 6 weeks

VI. Equine herpes I: Myelopathy

A. General information
1. Farm and individual animal history is very important
2. Affects any sex, breed, or reproductive status
3. Acute onset of posterior ataxia, paresis, or both
4. Thoracic limbs may be involved
5. Pelvic > thoracic
6. With or without cranial nerve deficits
7. Signs may be lateralized
8. Death may occur
9. Brain and spinal cord vasculitis with perivascular cuffing
10. May occur sporadically or in groups of horses
11. May follow abortions, respiratory tract disease

B. Diagnosis
1. Clinical signs
2. History of exposure
3. Most useful diagnostic test
 a. Polymerase chain reaction: Nasal swab, pharyngeal wash, buffy coat (earlier the better)
 b. Paired serum titer (4 × increase 10 to 14 days apart)
4. CSF titer
 a. Reflection of serum titer + blood-brain barrier permeability increase
 b. Xanthochromia, elevated temperature and pressure (>80 mg/dL), few to no mononuclear cells
5. Virus culture: Blood, nasal swab or wash
6. Pathology
 a. Vasculitis
 b. Liver, lung, buffy coat→ virus isolation

C. Treatment: Standard treatment for neurologic disease
1. Systemic antiinflammatories
2. Acyclovir (early treatment)
3. IV fluids
4. Nursing care

D. Prognosis: If not recumbent in the first 24 to 48 hours, pretty good prognosis

E. Prevention
1. Vaccination: Controversial
2. Vaccine not labeled for myelitis
3. Excessive vaccine use may actually be associated with disease

F. Controlling an epidemic
1. Relies on identifying infected horses, whether clinically or subclinically infected, through:
 a. Epidemiological tracing
 b. Combined with laboratory examination
2. Both clinically and subclinically infected horses can spread the virus

RESPIRATORY DISORDERS

I. *Rhodococcus equi* pneumonia

A. One of the most common causes of foal pneumonia

B. Clinical signs in foals
1. Coughing
2. Abnormal breathing patterns, rapid respiratory rate
3. Fever
4. Diarrhea less commonly
5. Age of onset is between 3 and 6 months of age
6. Abdominal involvement
7. Osteomyelitis
8. Hypopyon
9. Immune-mediated response
10. Polysynovitis
11. Immune-mediated response

C. Many farms are considered enzootic and seem to have problems year after year or every other year

D. Epidemiology
1. The adult horse carries *R. equi* in small numbers in their intestine, but they do not get sick
2. The organism can multiply in the intestine until up to 3 months of age so that the presence of foals actually contributes to the development of the infection on the farm
3. Foals with *R. equi* pneumonia swallow the mucus that accompanies the illness, and the bacteria end up back in the intestinal tract. Therefore, manure is likely a major source of contamination
4. The microbe can multiply up to 10,000-fold in manure, and the inhalation of dust particles laden with virulent *R. equi* results in a major exposure leading to pneumonic infection in foals

E. Diagnosis
 1. Clinical signs
 2. Clinical pathology
 a. Increased fibrinogen
 b. Elevated neutrophil count
 c. Elevated platelet count
 3. Transtracheal wash
 a. Gram stain
 b. Culture and sensitivity
 c. PCR
 4. Ultrasound examination: Single or multiple focal areas of pulmonary abscessation

F. Control
 1. The successful control of *R. equi* infections on enzootic farm depends on decreasing the size of the infective challenge, early recognition of the disease, and passive immunization
 2. The prime setting for an enzootic farm is a breeding facility in a warm or temperate climate with dust and wind
 3. Pneumonic foals should be isolated from the rest of the herd because they are a major source of contamination of the environment with virulent organisms
 4. Manure should be composted and not spread on nearby fields
 5. Immunization of mares and foals against common respiratory viral agents (influenza, equine herpesvirus types 1 and 4), an effective parasite control program, and adequate colostrum intake with detection and treatment of cases of failure of passive transfer may help by preventing potential predisposing illnesses
 6. *R. equi* antibody-rich plasma: Early administration (first 2 days of age) and then later (60 days of age) of 1 liter may be useful in preventing infections
 7. Monitoring: Frequent monitoring of foal's rectal temperatures, respiratory rate, complete blood cell count (CBC), and thoracic ultrasound or radiographs may help to identify early cases and allow early treatment with more positive treatment outcomes

G. Treatment
 1. Erythromycin phosphate (25-35 mg/kg every 12 hours, orally) and rifampin (5 to 10 mg/kg every 24 hours, orally) for at least 4 to 6 weeks, then 1 to 2 weeks after CBC and fibrinogen have normalized
 2. Azithromycin 10 mg/kg PO every 24 hours for 5 days, then every other day until resolution of disease + rifampin (5 mg/kg PO every 12 hours)
 3. Clarithromycin 7.5 mg/kg PO every 12 hours + rifampin 5 mg/kg every 12 hours until resolution

II. Strangles: *Streptococcus equi equi*

A. Also known as "strangles" because of the retropharyngeal and submandibular lymphadenopathy

B. β-hemolytic streptococcus

C. Tonsillar crypt invasion with attraction of numerous neutrophils, resistant to phagocytosis with a hyaluronic acid capsule and antiphagocytic M-protein

D. Guttural pouch invasion

E. May persist for months

F. Usually clears in a few weeks

G. Incubation period = 3 to 12 days (usually about 7 days)

H. Clinical signs
 1. Lethargy, anorexia, lymphadenopathy, bilateral nasal discharge, pharyngeal cattarh; lymph node abscessation
 2. Affects 1- to 50-year-old horses

I. *Very contagious*—Oral → nasal route of infection

J. Big potential for environmental contamination although doesn't survive long in the environment

K. Treatment
 1. Supportive care
 2. With or without penicillin G

L. Prevention is important!
 1. Vaccine: Controversial
 2. Isolate new animals 2 to 3 weeks
 3. Rectal temperatures twice daily

M. Management of infected animals
 1. Fly control
 2. Clean all equipment
 3. Disinfectants:
 a. Phenols (can use with organic material)
 b. Bleach and quaternary ammonium products require cleaning with detergent first. Ultraviolet (sunlight)

N. Test for "clearing": Nasal or pharyngeal swab 3 to 5 days in a row or guttural pouch lavage → submit for culture

III. Equine influenza

A. Orthomyxovirus

B. Antigenic variability (minor difference)—surface antigens
 1. Neuraminidase glycoproteins
 2. Hemagglutinin
 3. Two subtypes: 1 (H7H7) and 2 (H3N8)
 4. Subtype 2 is the important one causing outbreaks

C. Most common cause of upper respiratory tract infections

D. Sudden onset and short incubation period (1 to 3 days)

E. Ages affected: Usually 1- to 3-year-olds

F. Most susceptible: Mixing of youngsters (racetracks and shows)

G. Clinical signs
 1. High fever (106° F), may be biphasic
 2. Cough may last up to 3 weeks
 3. Lethargy
 4. Serous nasal discharge
 5. Some myopathies (creatinine elevations and reluctance to move)

H. Diagnostics
 1. CBC: Lymphopenia and eosinopenia early on and later monocytosis
 2. Paired titers = fourfold increase indicates recent infection

I. Pathogenicity
 1. Aerosol inhalation
 2. Attachment and propagation in epithelial cells of entire respiratory tract
 3. Decreased tracheal mucociliary rates (up to 32 days)

J. Horses recovering from infection may be unfit for racing for up to 100 days

K. Prevention: *Vaccination!* (appropriate)
 1. U.S. vaccines have (A/1, A/2) strains
 2. Initial vaccine, then booster every 3 to 4 weeks once or twice, then at least yearly

L. Do not forget about immunotolerance (foal will not mount a response because of interference of maternal antibodies)

IV. Equine herpes
 A. Herpes I
 1. Abortion
 a. Occurs in the last trimester of pregnancy
 b. Mares may abort the fetus standing up
 c. Fetus is covered with intact amnion, allantochorion, or both
 d. Occasionally a live foal is born but dies shortly afterward
 e. Abortion "storms" are rare but can occur
 2. Herpes I: Respiratory disease
 a. Self-limiting upper respiratory disease with biphasic fever lasting 8 to 10 days, peaking 1 to 2 days after infection. There is serous nasal discharge, depression and anorexia, conjunctivitis, and serous ocular discharge
 b. Nasal discharge is mucoid or mucopurulent
 c. Some horses develop secondary bronchopneumonia
 d. Some horses develop poor-performance syndrome
 3. Myelitis (discussed under neurologic disease below)
 B. Herpes IV causes respiratory disease, with clinical signs similar to equine herpes virus type 1 respiratory form
 C. Vaccination
 1. Bivalent vaccine: Herpes I and IV
 2. Killed vaccine
 a. 5, 7, and 9 months of gestation
 b. Some veterinarians administer at 3 months

V. Equine adenovirus
 A. Severe respiratory disease in Arabian foals with combined immunodeficiency disease
 B. Clinical signs
 1. Cough
 2. Fever
 3. Tachypnea
 4. Nasal and ocular discharges
 C. Little consequence except in immunocompromised foals

VI. Equine viral arteritis
 A. One serotype of an arterivirus
 B. Standardbreds are susceptible (more so than other breeds)
 C. Abortion and respiratory disease; morbidity is high; can cause death
 D. Causes a panvasculitis—respiratory and reproductive; highly contagious
 E. There is an effective vaccine, although its use is regulated both federally and by individual states
 F. Outbreak in Illinois in early 1990
 G. Differential diagnosis is purpura, EIA, African horse sickness (AHS)

VII. AHS
 A. AHS: Foreign animal disease; spread by culicoides, not contagious
 B. Similar in morphology to bluetongue, which is a reoviru
 C. Africa, Asia, Middle East, Spain
 D. Diagnosis by reverse transcriptase-PCR

VIII. Equine morbillivirus
 A. Zoonotic!
 B. Killed 21 horses and 1 human in Australia
 C. Clinical signs
 1. Pulmonary edema
 2. Interstitial pneumonia
 3. Hemorrhagic pneumonia
 4. Dilated lacteals
 D. 8- to 14-day incubation period
 E. Fruit bat may be a natural reservoir for the virus
 F. Urine may have active virus and responsible for causing infection when in contact

IX. Anthrax
 A. *Bacillus anthracis* is a resilient spore-forming bacterium which lives in the ground
 B. Vaccine: Use *before* an outbreak; live nonencapsulated spores
 C. Do not use antibiotics within 1 week of vaccination
 D. Naturally occurs in Texas and other Great Plains states
 E. Occasional occurrence in horses
 F. Livestock ingest *B. anthracis* when they forage close to the ground during drought or when they eat feed grown on infected soil. Horses seem to be more resistant to anthrax than are other livestock species, such as sheep or cattle. Naturally occurring anthrax appears in Texas from late June through September and October, and outbreaks end with the start of cooler weather
 G. Wet period followed by hot or dry spells can trigger the germination of dormant anthrax spores in the ground, causing them to migrate to the surface and contaminate soil and grass
 H. Three forms exist
 1. Cutaneous
 2. Inhalation
 3. Intestinal, although clinical signs in the horse are characterized by a high fever (up to 107° F) and a quick death
 I. Rigor mortis is absent or incomplete in an anthrax carcass
 J. Horses frequently have ventral edema (swelling on the underside of the body), are fevered, and are obviously "sick"
 K. Horse carcasses often have dark blood oozing from the mouth, nostrils, and anus. Diagnosis can be based on these clinical signs, but

laboratory confirmation is based on finding *B. anthracis* in a blood sample or blood culture. Carcasses infected with anthrax must be burned

L. Disease is reportable

X. Glanders (foreign animal disease)
 A. Fatal equine disease caused by *Pseudomonas mallei* (or *Burkholderia mallei*)
 B. Present in African and Asian countries
 C. Not in the United States
 D. Contracted via ingestion of food or water with infectious organisms. Sometimes contracted via inhalation and contact
 E. Characterized by formation of nodules, ulcerations and degenerative changes. Presents in three forms (can all be seen together)
 1. Pulmonary
 2. Nasal
 3. Cutaneous (farcy)

Note: For infectious diseases of the GI tract, see Chapter 36, Gastrointestinal Diseases.

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.

Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St Louis, 2009, Saunders.

Sellon DC, Long MT. *Equine Infectious Diseases.* St Louis, 2007, Saunders.

Smith BP. Large *Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

38 CHAPTER

Nervous System Disorders

Rebecca S. McConnico

NEUROLOGIC EVALUATION

I. Patient profile and history
 A. Signalment: Age, sex, breed, use (pasture pet, pleasure, athlete, breeding)
 B. Time course of events
 C. Initial problem: Peracute, acute, insidious, subtle, mild, moderate, severe
 D. Associated events: Thunderstorm, trailering, breeding, history of disease, introduction of new animals, veterinary procedures
 E. Vaccination status: Equine herpesvirus types 1 (EHV-1) and 4 (rhinopneumonitis), influenza, eastern equine encephalitis (EEE), western equine encephalitis (WEE), Venezuelan equine encephalitis (VEE), West Nile virus (WNV), *Streptococcus equi equi*, rabies
 F. Feeding program
 G. Abnormalities observed by the owner, such as changes in attitude at rest or work, appetite, interaction with other animals (aggressive actions, avoidance)

II. Physical and neurologic examination
 A. Routine physical examination: Includes several basic neurologic tests that will usually tell the examiner whether a further detailed assessment of the neurologic system is necessary
 1. Attitude
 2. Eyes: Menace, pupillary light reflex (PLR), fundoscopic examination
 3. Head: General symmetry (bony and soft tissues), tongue inspection, laryngeal adductor-abductor test (external "slap" test, performed by palpating the dorsolateral larynx while slapping the opposite side of the withers)
 4. Neck, trunk, and limbs: Observe for normal bony and soft tissue symmetry
 5. Tail and anal tone (can be done at the time of rectal temperature determination or rectal examination)
 6. Evaluation of gait and posture at the walk
 B. Specific neurologic examination (three parts = head + body + posture or gait)
 1. Behavior: Input from owner, trainer, groom, rider (distinguish between bad habits and changes suggestive of neurologic disease)
 2. Mentation: Depression
 a. Systemic illness
 b. Cerebrum
 c. Reticular activating system (limbic system)
 3. Head posture and movement
 a. Standing still
 (1) Head tilt (poll deviated from the muzzle), vestibular
 (2) Head turn: Forebrain or cervical injury
 (3) Intention tremors: Cerebellar
 b. Moving to prehend food (offer handful of grass, sweet feed, or alfalfa hay)
 c. Moving during gait evaluation
 4. Cranial nerves (CNs)
 a. Eyes
 (1) Menace = positive blinking; intact vision in respective eye (ipsilateral eye and optic nerve; contralateral optic tracts and lateral geniculate nucleus)
 (2) PLR: Use a strong, focused light held about 18 inches in front of the horse and perform swinging light techniques
 (3) Elevate head to observe normal eye drop; then, while head is elevated, move head from side to side to induce normal vestibular nystagmus
 (4) Symmetric positioning of the eyes: CN III (oculomotor), IV (trochlear), VI (abduscens), VIII (vestibulocochlear connection with the brainstem)
 b. Head and face
 (1) Symmetry of bones and soft tissue
 (2) CN V (trigeminal): One of the largest nuclei in the brainstem: innervates muscles of mastication and sensory to the face and nostrils. Injury leads to dropped jaw and ipsilateral loss (or partial loss) of sensation to the face and inside the nares
 (3) Voluntary movement of the ears, eyelids, lips: CN VII
 (4) Touch: Ear → ear movement; eyelid → lid closure; lip commissure → induced smile; evaluation of sensory/trigeminal (CN V) and motor-facial (CN VII) reflexes
 c. Nostrils, mouth, throat
 (1) Stimulate each surface of the nasal septum = asymmetric response; suggests possible CN V (trigeminal)
 (2) Tongue: Weakness and fine muscle fasciculation; hypoglossal and glossopharyngeal (CN XI and IX)

(3) Larynx and pharynx: Upper airway endoscopy; visual examination, internal exam (vagus, glossopharyngeal, and accessory, CN X, XII, IX)

d. Horner syndrome: Cranial sympathetic denervation characterized by various symptoms in the head and cervical region
(1) Blepharoptosis
(2) Enophthalmos
(3) Prolapse of the third eyelid: Retraction of the eyeball due to paralysis of the orbital smooth muscle
(4) Miosis: Removal of sympathetic innervation of the dilator papillary muscle
(5) Increased secretion of lacrimal or nasal glands
(6) Increased cutaneous temperature: Direct results of hyperemia in denervated regions; lack of sympathetically-induced vasoconstriction which is normally mediated by α-receptors in cutaneous blood vessels
(7) Local sweating: Sweat-induced vasomotor activity of circulating epinephrine
(8) Laryngeal hemiplegia: Vasosympathetic trunk and recurrent laryngeal nerve ("slap test")

5. Body
a. Neck and thoracic limbs or trunk and pelvic limbs
(1) Body and muscular symmetry
(2) Evidence of localized sweating, focal muscle atrophy, decreased pain response, localized pain response (variability)
(3) Cutaneous trunci reflex: Cervicothoracic reflex (panniculus); stimulates vertebral column movements
b. Tail and anus
(1) Tail tone
(2) Anal reflex
(3) Rectal examination

6. Posture and gait: Evaluated at rest, walking, trotting, turning, on an incline, freely moving in a confined pasture, paddock, or arena
a. General proprioception (conscious proprioception [CP] deficits or CP deficits)
b. Backing: Resistance to movement, lack of coordinated leg lifting
c. Negotiating obstacles (stepping over curbs)
d. Tight circling
e. Weakness
(1) Low arc and longer stride length
(2) Toe dragging
(3) Muscle tremor buckling
(4) Tail-pull resistance
(5) Hopping
f. Ataxia: Inability to control muscle coordination
g. Spasticity dysmetria
(1) Hypometria: L4-S5
(2) Hypermetria (spasticity): T3-L3 → pelvic limb
(3) Degrees of mild ataxia may be expressed with other postural movements
(4) Elevating the head and walking and tight turning
h. Paralysis or paresis (loss or partial loss of motor function)
(1) Paraplegia: Pelvic limb lesion = T3-S5; lower motor neuron (LMN) L4-S5
(2) Tetraplegia: Thoracic and pelvic limb; upper motor neuron (UMN) pelvic limb
i. Grading neurologic gait deficits
(1) 0 = no gait deficits
(2) 1 = difficult to observe but consistently observed
(3) 2 = mild to moderate deficit; exaggerated on the slope or in circles
(4) 3 = obvious to all observers when the horse moves
(5) 4 = manipulations may cause the horse to fall
(6) 5 = recumbency

7. Specific neuroanatomic diagnosis
a. Cerebrum: Abnormal behavior, seizures, depression, blindness, pseudocranial nerve changes
b. Brainstem and peripheral CNS: Depression, ataxia and weakness, specific CN deficits
c. Cerebellum: Menace deficit without blindness, intention tremor, base-wide ataxia with dysmetria
d. Spinal cord: Degrees of ataxia and weakness
e. Peripheral spinal nerves: Localized weakness, muscle atrophy, sensory loss
f. Muscular: Stiff and weak gait, local painful response elicited by palpation

C. Ancillary diagnostic tools
1. Blood and serum analysis
a. Serum chemistry
(1) Muscle: Alkaline phosphatase, creatinine phosphokinase
(2) Liver: Alkaline phosphatase, sorbitol dehydrogenase, aspartate amino transferase, γ-glutamyltransferase (GGT)
(3) Kidney: Blood urea nitrogen (BUN), creatinine
b. Serum electrolytes
c. Total white blood cell count (WBC)
d. Red blood cell (RBC) indices
e. Serology: Titers (EEE, WEE, WNV, VEE, equine infectious anemia [EIA], EHV-1, equine protozoal myelitis [EPM])

2. Imaging
a. Standing survey: Sagittal spinal column measurements
b. Nuclear scintigraphy
c. Myelography

3. Cerebrospinal fluid (CSF) analysis
a. Atlanto-occipetal (AO) cisternal space (requires general anesthesia)
(1) Landmarks are the cranial borders of the atlas and the external occipital protuberance on the dorsal median plane

(2) Use a 3-in spinal needle (18 G) with a stylet
(3) Key: Aim for the lower lip with the head in a very flexed position

b. Lumbosacral space, standing; requires tranquilization or recumbent patient (Figure 38-1)
(1) Landmarks are the caudal borders of the tuber coxae, the caudal edge of L6, the cranial edge of the second sacral spine, and the cranial edge of tuber sacrale
(2) Needle passes through skin → lumbosacral fascia → interarcuate ligament → dorsal dura mater → arachnoid → subarachnoid space

4. Electrodiagnostics
a. Electromyelography (EMG) for LMN disease
b. Electroencephalography for cerebral-cerebellar-brainstem lesions
c. Auditory: Evoked potentials; hearing pathways
5. Necropsy

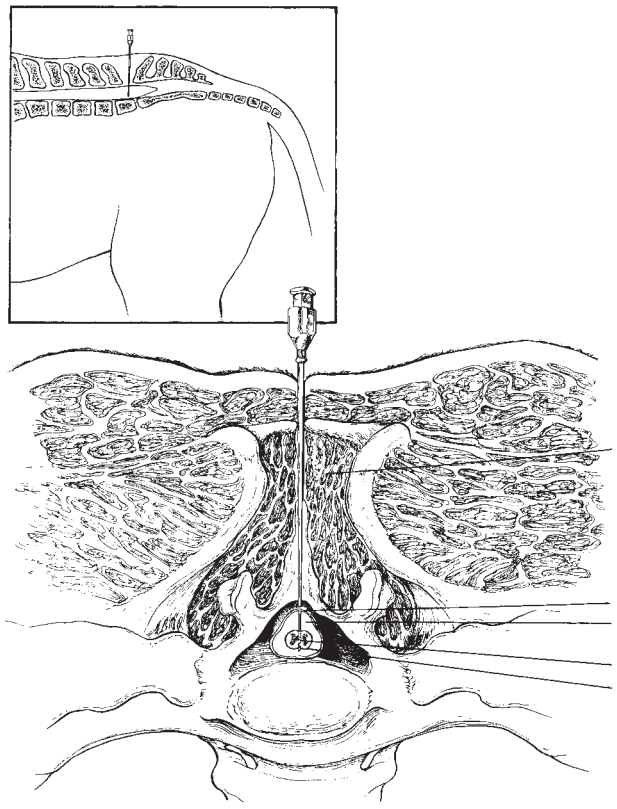


Figure 38-1 Lumbosacral spinal fluid collection from a horse showing the various tissue layers that the spinal needle must pass through to obtain a sample. The spinal fluid is collected ventral to the spinal cord in the subarachnoid space. *Inset,* Lateral view of spinal needle placement in the lumbosacral space for collection of cerebrospinal fluid. (From Andrews FM, Adair HS III. Anatomy and physiology of the nervous system. In Auer JA, editor. *Equine Surgery*. Philadelphia, 1992, Saunders; modified from deLahunta A. *Veterinary Neuroanatomy and Clinical Neurology,* 2nd ed. Philadelphia, 1983, Saunders; From Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine*, 2nd ed. St. Louis, 2004, Saunders)

ADULT NEUROLOGIC DISORDERS

I. Cervical vertebral instability (CVI), cervical vertebral malformation (CVM), cervical vertebral stenosis (CVS), cervical static stenosis (CSS)
A. Pathophysiology
1. CSS: Static lesion usually seen at C5-6 or C 6-7
2. CVI: Dynamic lesion usually seen at C 3-4 and C 4-5. Stenosis of vertebral canal, malformed articular processes, angular fixations; pathologic impingement on the cervical spinal cord, osteochondral lesions, focal cervical contusions; damage to white, gray matter (ventral and lateral tracts); secondary white-matter fiber degeneration; ascending pathway above lesion descending pathway below lesion; blood-brain barrier alterations; demyelination, remyelination, long-lasting ischemia, and venous occlusion

B. Signalment
1. Young, rapidly growing males
2. Age 4 months to 4 years
3. Rare in older horses unless it has gone unrecognized
4. Breed predilection: Thoroughbred, standardbred, warmblood
5. Both males and females can be affected

C. History
1. Subtle gait abnormalities in weanling or yearlings
2. Usually presented for lameness or wobbliness soon after athletic training begins; often presented after a fall → acutely ataxic
3. Neurologic examination: Localized to the cervical vertebrae

D. Clinical signs
1. Various degrees of spinal ataxia
2. UMN: Dysmetria, spasticity, and paresis of pelvic, thoracic limbs
3. Neurologic examination: Localized to cervical vertebrae

E. Differential diagnosis
1. Lameness
2. EHV-1 myelitis
3. Cerebellar hypoplasia (Arabians)
4. Equine degenerative myeloencephalopathy (EDM)
5. Fracture
6. EPM
7. Verminous arteritis
8. Mass (abscess)

F. Diagnosis
1. Neurologic examination
2. Survey radiography
a. Overgrowth of cranial articular process (C2-C6)
b. Narrowing of cervical vertebral canal
c. Enlarged vertebral epiphysis
d. Enlarged dorsal prominence of caudal epiphysis (ski slope)
e. Dorsal displacement, subluxation of vertebral head (neck flex)

f. May have osteochondral fragmentation at intervertebral articulation

3. Myelogram
 a. Natural, extended, and flexed
 b. Narrowing of dorsal and ventral dye column (at least 50% or greater narrowing of the dorsal contrast column is necessary for a diagnosis)
4. CSF
 a. Usually normal, occasionally xanthochromic (yellow), normal pressure
 b. EMG: May have LMN abnormalities in neck muscles

G. Treatment
1. Rest
2. Restrict energy intake
3. Early weaning (in early recognized cases)
4. Medical decompression (nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids, dimethyl sulfoxide [DMSO])
5. Surgical decompression

II. Equine protozoal myelitis (EPM)

A. Introduction
1. Debilitating equine neurologic disease of horses
2. Affects the brain, brainstem, spinal cord, or any combination of these three areas of the central nervous system (CNS)

B. Cause
1. Caused by *Sarcocystis neurona*
2. Life cycle: *S. neurona* (Figure 38-2)
 a. Horse is a dead-end aberrant host
 b. Infectious forms of the parasite are not passed from horse to horse or from horse to the definitive or true intermediate hosts
 c. Definitive host: Opossum, and other mammalian species feces (definitive host) are the source of the infection for horses
 d. Opossums acquire the infection by eating infected birds (intermediate hosts)
 e. Most infections come from contaminated pasture, hay, grain, and water with opossum feces. Contamination of feed and water with opossum feces may occur indirectly through other mechanisms such as birds and insects
3. Most horses in North America test positive for *S. neurona* antibodies
 a. Exposure to the parasite, not necessarily the presence of disease, the incidence of which is much lower

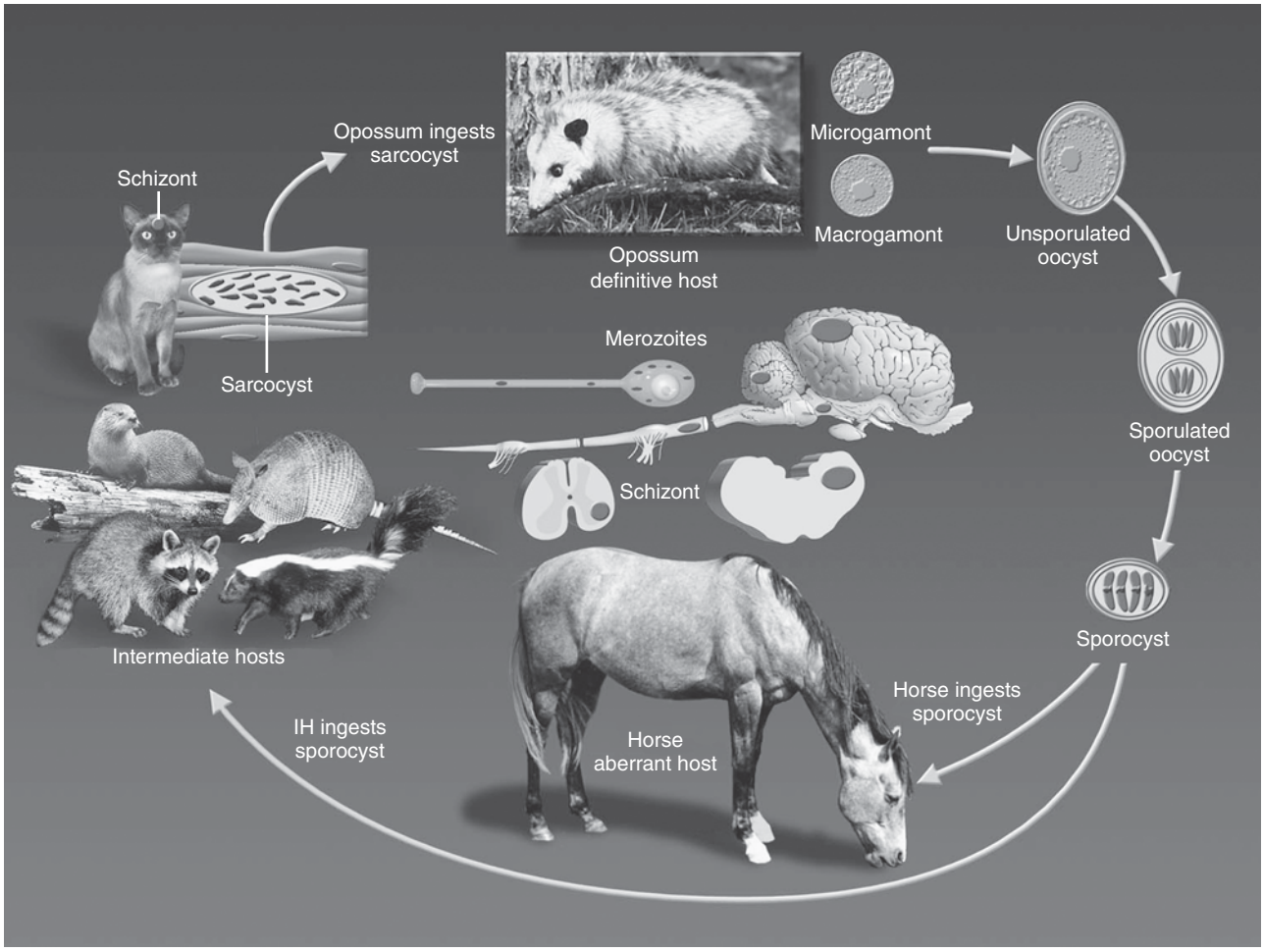


Figure 38-2 Life cycle of Sarcocystis neurona. (Photo courtesy of Dr. William J.A. Saville, The Ohio State University, Columbus, Ohio.) (From Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine*, 2nd ed. St. Louis, 2004, Saunders)

b. In the studies that looked at the distribution of seropositive cases geographically, it was found that climatic factors can affect exposure rates; an increase in the number of freezing days was associated with a decrease in numbers of horses exposed to the parasite
c. A similar effect of very hot environments may also decrease the survival of the infective stages of the protozoan parasites and lessen exposure to horses. EPM appears to have a sporadic distribution, although outbreaks have been reported on farms in Kentucky, Ohio, Indiana, Michigan, and Florida

C. Signalment
1. Horses most at risk for acquiring EPM
a. Young horses (2- to 4-year olds)
b. Standardbreds, thoroughbreds, quarter horses
c. Both males and females
d. Horses in training, horses at rest
2. EPM can affect a horse of any age, breed, or sex. The youngest horse reported to be affected was 2 months old, the oldest in its 30s

D. Clinical signs
1. EPM is a progressive disease, which if not treated can eventually lead to death
2. Any horse that is demonstrating neurologic abnormalities may have EPM
3. May present with a variety of different clinical signs, dependent on the location of the damage caused by the organism within the CNS. Can cause focal or multifocal disease
4. Clinical signs may be triggered or worsened by physiologic stress or the administration of corticosteroids
5. Clinical signs of the disease include weakness, malposition of a limb, muscle atrophy, spinal ataxia, or "wobbling" head tilt with asymmetry of the face (eyelid, ear, lip)
6. More severe clinical signs reveal a severely EPM-affected horse that may be down and unable to rise. Lameness not traceable to orthopedic disease or any combination of the above signs may occur in early or less severe infections. Other unusual signs may occur
7. Many horses with protozoal myelitis are bright and alert with a normal appetite, although some horses are dysphagic
8. Hematologic and biochemical blood values are usually in the normal range
9. Sometimes a horse may have more than one disease, for example, both EPM and cervical stenotic myelopathy ("wobbler")

E. Diagnosis
1. Based on clinical signs, ruling out other causes of neurologic disease, and on testing of the horse's CSF
2. The Western blot test of CSF detects antibodies. Blood contamination of CSF may result in a false-positive test.

F. Treatment
1. No effective vaccine is currently available
2. Antiprotozoal treatment
a. Ponazuril: Approved EPM therapy for horses
b. Nitoxanide: Approved EPM therapy for horses
c. Pyrimethamine-sulfadiazine combination
3. Supplementation with folic acid (40 mg orally, once a day) may help prevent adverse side effects. Folic acid should not be administered at the same time as the antimicrobial drugs
4. In cases with severe neurologic signs, NSAIDs and DMSO may be added to the treatment regimen

G. Prognosis
1. Early detection and therapy will increase the chance of successful treatment
2. Many treated horses return to their original level of function; however, some may not respond completely
3. Approximately 10% of cases relapse after treatment is discontinued
4. Some horses are currently on medication indefinitely

III. Equine degenerative myeloencephalopathy (EDM)
A. Signalment
1. Recognized in all species
2. Familial predisposition
a. Appaloosa
b. Standardbred
c. Pasa Fino
d. Morgan: Neuraxonal dystrophy of the cuneate nucleus
3. Age: 1 to 10 years (usually occurs in young horses)
4. Permanent neurologic deficits
5. Predisposing factors
a. Vitamin E deficiency
b. Exposure to wood preservatives
c. Copper deficiency

B. Differentiating characteristics on neurologic examination
1. Pelvic limbs → thoracic limbs
2. Thoracic → pelvic limbs
3. Thoracic = pelvic limbs
4. Reflexes may be absent
a. Cutaneous trunci
b. Focal cervical
c. Cervicothoracic
d. Slap reflexes
5. No CN deficits

C. Treatment: Massive vitamin E supplementation

IV. Verminous myelitis
A. Signalment
1. Any breed, sex, age (older than 6 months)
2. Mild to severe and fatal

B. Diagnosis
1. Clinical signs
2. CSF
a. Usually normal
b. Advanced cases
(1) Xanthochromic

(2) Cytology - pleocytosis
(3) Elevated protein

C. Treatment
1. Intravenous (IV) DMSO
2. NSAIDs
3. Larvacidal anthelmintic
4. Fenbendazole: 60 mg/kg once or 50 mg/kg every 24 hours (3 days), 7.5 mg/kg every 24 hours (5 days)

V. Herpes myelitis
A. Pathophysiology
1. Vasculitis
2. Brain and spinal cord vasculitis with perivascular cuffing
3. Liver, lung, buffy coat → virus isolation

B. General information and clinical signs
1. Farm and individual animal history very important
2. Any sex, breed, or reproductive status
3. Acute onset of posterior ataxia or paresis
4. Thoracic limbs may be involved
5. Pelvic → thoracic
6. With or without CN deficits
7. Signs may be lateralized
8. Death may occur
9. May occur sporadically or in groups of horses
10. May follow abortions, respiratory tract disease
11. CSF analysis
a. Xanthochromic
b. Elevated total protein (>80 mg/dL)
c. Few to no mononuclear cells

C. Diagnosis
1. Polymerase chain reaction (PCR): Nasal swab, pharyngeal wash, buffy coat (earlier the better)
2. Paired serum titer (4 × increase 10-14 days apart)
3. CSF titer: Reflection of serum titer + blood-brain barrier permeability increase
4. Virus culture: Blood, nasal swab, or wash

D. Treatment
1. Standard neurologic treatment
2. Antiinflammatories
3. Acyclovir (early treatment)
4. IV fluids
5. Nursing care

E. Prognosis. If not recumbent in the first 24 to 48 hours, there is a fairly good prognosis

F. Prevention
1. Vaccination: Controversial
2. Vaccine not labeled for myelitis
3. Excessive vaccine use may actually be associated with disease

G. Controlling an "outbreak"
1. Relies on identifying infected horses, whether clinically or subclinically infected
2. Epidemiologic tracing
3. Combined with laboratory examination
4. Both clinically and subclinically infected horses can spread the virus

H. Positive case
1. Positive PCR or virus isolation (nasal swab or wash, buffy coat)
2. Neurologic signs
3. Association with an EHV-1 neurologic case
4. More than incidental exposure
5. Stabling
6. Transport
7. Tended to by the same stabling crew
8. Horse may have had a fever
9. Horse has positive PCR (nasal swab, buffy coat)

I. Suspect case
1. Association with an EHV-1 neurologic case
2. More than incidental exposure
3. Stabling
4. Transport
5. Tended to by the same stabling crew
6. No positive EHV-1 tests
a. Negative
b. Not performed
c. Pending

J. Quarantine
1. 21-28 days for those exposed to a positive EHV-1 case
2. Red zone: Higher risk, same barn (35-foot distance)
3. 7-day quarantine for the event site (track, farm, hospital, etc.)
4. Yellow zone
5. Green zone
6. Reportable disease

VI. Polyneuritis equi
A. Pathophysiology
1. Similar to Guillain-Barré syndrome
2. Immune-mediated (may be viral associated)
3. Anti-myelin proteins (P2 proteins)

B. Signalment
1. Affects adult horses
2. Cauda equina neuritis
3. Caudal spinal cord neuropathy = L5
4. Acute to insidious onset of tail or head hyperesthesia
5. Gradual paralysis of tail, bladder, rectum causing pelvic limb ataxia

C. Lesions
1. Necropsy
a. Thickened cauda equina
b. Edematous, fibrous, adhesions
2. Histopathology: Granulomatous inflammation

D. Clinical signs
1. Fecal retention
2. Anal dilation
3. Urinary incontinence: Bladder, loss of parasympathetic control
4. Paraphimosis
5. May have CN deficits; motor branch of CN V

E. CSF analysis: Elevated protein

F. Treatment
1. Steroids
2. Supportive care
3. Usually requires euthanasia

VII. Tail alterations in show horses
 A. Elective mutilation
 B. Elective cauda equine neuritis
 C. Goal of tail blocks: No tail ringing, no arch in tail, appearance of relaxation
 D. Surgical: Target locations
 1. Sacrocaudalis medialis
 2. Sacrocaudalis lateralis
 E. Chemical (95% ethanol): Target location is the paravertebral nerve

PERIPHERAL NEUROPATHIES AND NEUROMUSCULAR DISEASES

I. Equine LMN disease
 A. Components of the motor unit
 1. Dorsal root of spinal nerve
 2. Dorsal root ganglion
 3. Lower motor neuron
 4. Muscle spindle
 5. Terminal "arborization" of LMN axon
 6. Ventral nerve of the spinal nerve
 B. Pathophysiology: Damage to the following:
 1. α-motor neuron cell body
 2. α-motor neuron axon
 3. Myelin sheath Schwann cells
 4. Neuromuscular junction
 5. Muscle fiber
 C. Clinical signs
 1. Generalized weakness
 2. Muscle atrophy
 3. Tremors
 4. Obscure lameness

II. Botulism
 A. Pathophysiology
 1. Exotoxin results in muscular weakness
 2. Toxins: A, B, C1, C2, D, E, F, G
 a. B is most common affecting horses
 b. A and B causes forage poisoning (toxin in the hay)
 c. C is usually a result of rotting carcasses
 B. Routes of infection
 1. Ingestion of preformed toxin
 2. Ingestion of spores leading to toxicoinfectious botulism (shaker foal syndrome)
 3. Contamination of wounds
 C. Shaker foal (toxicoinfectious botulism)
 1. Bright, robust foal that lies around much more often
 2. May drool and tongue may be weak (i.e., easy to pull from its mouth); dysphagia
 3. Mild mydriasis and eyelid droop
 4. Weakness progresses to recumbency
 a. 2- to 3-week duration
 b. Needs supportive care (enteral feeding tube, may need ventilator)
 D. Forage poisoning (adult form of botulism)
 1. Pathophysiology
 a. Toxin acts presynaptically at peripheral cholinergic neuromuscular junction by blocking acetylcholine
 b. Results in flaccid paralysis
 2. Clinical signs
 a. Generalized muscle weakness
 b. Progresses to recumbency (ileus)
 c. Reduced tongue strength (tongue stress test)
 d. Eating test (grain mixed with saliva): Normal horse should be able to clean up the grain in 2 minutes or less (8 oz)
 e. Decreased tail tone
 f. Muscle trembling
 g. Moderate mydriasis, decreased PLR
 3. Diagnosis
 a. Clinical signs
 b. Demonstration of preformed toxin in the serum, gastrointestinal (GI) contents (feces – 34% in some cases), wound
 c. Demonstration of *Clostridium botulinum* spores in the GI tract or feed materials
 d. Antibody response in recovering cases
 e. Mouse bioassay requiring 5 mL of serum from the suspect animal
 f. PCR botulinum neurotoxin
 4. Treatment
 a. Antitoxin (12 hours half-time)
 (1) 200 mL or 30,000 international units (IU) for foal
 (2) 500 mL or 70,000 IU for adult
 b. Only effective with unbound toxin
 c. Supportive care: Enteral feeding support (twice daily for adults)
 5. Prevention: Toxoid (3 ×, 30 days apart)

III. Equine motor neuron disease
 A. First described in 1990; similar to the human disease atrophic lateral sclerosis, or Lou Gehrig disease
 B. Pathophysiology
 1. Noninflammatory degeneration
 a. Ventral horn of spinal cord gray matter (LMN)
 b. Nuclei of CN V, VII, and XII
 c. Nucleus ambiguous
 2. Neurogenic atrophy of muscles (especially type 1 myofibers; higher susceptibility to oxidative stress)
 3. Requires 30% motor neurons affected
 C. Signalment
 1. Sporadic in individual animals
 2. Few reports of "herd outbreak"
 3. Horses without access to pasture
 4. Horses with access to poor quality feed/hay and/or only pelleted diets
 5. Occurs in northeastern United States and Canada
 D. Clinical signs
 1. Mean age = 9 years (range, 2 to 23 years)
 2. Subacute form
 a. Trembling and muscle fasciculations
 b. Frequent weight shifting
 c. Head carriage is abnormally low
 d. About 1-month duration of weight loss
 3. Chronic form
 a. Generalized muscle atrophy
 b. May look emaciated

c. Tail head is in high resting position
d. Generalized muscle atrophy despite normal appetite
e. Generalized weakness
f. Short-strided gait
g. Low head carriage
h. Feet positioned well under body
i. Shifting weight
j. Excessive recumbency
k. Excessive sweating, especially after exercise
4. Subclinical form
a. Diminished strength
b. Difficult to diagnose

E. Clinical pathology
1. Creatinine kinase increased
2. Aspartate aminotransferase increased
3. Low serum vitamin E (i.e., less than 1 μg/mL)
4. RBC superoxide dismutase decreased
5. Elevated GGT
6. Low vitamin A and C levels
7. Low β-carotene levels
8. High iron levels

F. Gross changes
1. Muscle pallor
a. Medial head of triceps brachii and vastus intermedius muscle
b. Sacrocaudalis dorsalis medialis
2. Severe degeneration and fibrosis of muscle
3. Pigment retinopathy
4. Deposition of lipopigment in vasculature of spinal cord

G. Diagnosis
1. History
a. History of previous cases in the stable
b. Horse without access to green forage
c. Horse without access to vitamin E
2. Low vitamin E serum levels
3. Muscle or nerve biopsy
a. Sacrocaudalis dorsalis muscle (90% sensitivity and specificity)
b. Denervation atrophy and scattered fiber atrophy
c. Spinal accessory nerve biopsy

H. Differential diagnosis: Differentiate from botulism
1. No dysphagia
2. Normal tone
3. Bladder
4. Anal
5. Tongue
6. Slow, insidious onset over several months

I. Treatment
1. 5000-7000 IU of vitamin E daily
2. Full recovery is unlikely

J. Prevention = green grass

IV. Sorghum toxicity
A. Ataxia and cystitis in horses
B. Difficulty backing, may fall over
C. Diagnosis: Ataxia, urine dribbling and history of feeding sorghum

V. Tetanus
A. Pathophysiology
1. Caused by *Clostridium tetani*, a soil contaminant
2. Incubation period is 2 weeks to 1 month after bacterial inoculation
3. Logarithmic growth phase
4. Three toxic proteins:
a. Tetanospasmin
b. Tetanolysin
c. Nonspasmogenic toxin
5. Toxin binds to presynaptic part of the motor endplate and α-motor neuron binding
6. Toxin inhibits release of glycine and γ-aminobutyric acid (GABA) (inhibits the inhibitors)
7. Causes muscle rigidity, spasms, hypertonicity

B. Clinical signs
1. Horse has increased risk of tetanus
2. Muscular rigidity and death
3. Respiratory arrest
4. Convulsions

C. Treatment
1. Provide muscle relaxation
2. Ensure good footing
3. Eliminate infection
4. Neutralize unbound toxin
5. Antitoxin dose: 1000 to 5000 IU/500 kg to 1000-5000 IU/kg
6. Maintain hydration and nutritional status

D. Prognosis: Mortality rate in horses = about 80%

VI. Hyperkalemic periodic paralysis
A. Pathophysiology
1. Phenylalanine-leucine substitution in skeletal muscle sodium channel α-subunit
2. Autosomal dominant
3. Familial disease in humans and quarter horses

B. Clinical signs
1. Episodic and generalized weakness
2. Laryngeal paralysis
3. Muscle fasciculations
4. Prolapse of the third eyelid
5. Recumbency

C. Diagnosis: DNA testing (need 50 mane or tail hairs)

VII. Stringhalt
A. Pathophysiology
1. Demyelination: Distal axonal degeneration selectively involving large myelinated nerve fibers
2. Fibrosis
3. Schwann cell proliferation
4. Denervation atrophy (Type 2 myofibrils)
5. Plant toxicity in some cases: *Hypocheuris radicata*

B. Clinical signs
1. Hyperflexion of one or both hocks
2. Sporadic or epidemic
3. Abrupt onset of continuous or intermittent hyperflexion of one or both hindlimbs during motion
4. Severe horses may bunny hop
5. May worsen in cold weather
6. May worsen when backed
7. Seasonal: Late summer-early autumn; dry weather

C. Diagnosis is based on clinical signs
D. Prognosis is poor, as recovery is rare

VIII. Shivers
 A. No known toxic plant has been linked to this condition despite the fact that it resembles stringhalt and lathyrism
 B. Greater prevalence in draft horses
 C. Clinical signs
 1. Tremors of the large muscles of the upper leg
 2. Flexion of one or both hindlimbs
 3. When the horse is forced to back up or exercise, this gait problem is easily seen
IX. Sweeney
 A. Pathophysiology
 1. Injury to the suprascapular nerve
 2. Atrophy of the infraspinatus and supraspinatus muscles
 B. Clinical signs
 1. Looks like a dislocated shoulder to the owner
 2. Commonly seen in harness-wearing draft horses
 3. Treatment: Surgery. Make a groove in the scapula
X. Radial nerve paralysis: Horses have a dropped elbow and cannot extend the limb
XI. Femoral nerve paresis-paralysis: Horses cannot bear weight on the hindlimb
XII. Myotonia congenital
 A. Pathophysiology
 1. Variable muscle fiber size
 a. Type 1 and type 2 fibers
 b. Ringed fibers
 2. Alterations in shape and size of nuclei
 3. Genetic (probably)
 4. Abnormal sarcolemmal chloride conductance (in humans and goats)
 B. Signalment
 1. Affects humans, horses, goats, mice, and dogs
 2. Usually detected in the first year of life
 C. Clinical signs
 1. Well-developed musculature
 2. Mild pelvic limb stiffness
 3. Bilateral bulging (dimpling), especially with initial exercise
 4. Muscles stay contracted; slow to relax
 5. Associated with retinal dysplasia, lenticular opacities, and gonadal hypoplasia; quarter horse foal
 D. Diagnosis
 1. Characteristic clinical signs
 2. Delayed relaxation after contraction, dimpling
 3. EMG: Crescendo-decrescendo, high-frequency repetitive bursts, "dive-bomber" signs with insertion of electrode needle
 E. Treatment
 1. Phenytoin (has been effective in some cases)
 2. *Do not breed these horses*!
 F. Prognosis: May have functional life
XIII. Postanesthetic myopathies
 A. Myopathy, neuropathy, or both. May see emergence delirium
 B. Treatment
 1. Antiinflammatory agents
 2. IV fluids
 3. Rest
XIV. Hypocalcemic tetany
 A. Pathophysiology
 1. Lack of nerve cell membrane stabilization
 2. Causes
 a. Calcium pool deficit
 b. Metabolic alkalosis with normal total calcium. Ionized calcium decreases as the increased pH promotes protein-binding of calcium
 c. Normal total calcium with hyperkalemia or hypochloremia
 B. Clinical signs
 1. Tonic spasms
 2. Decreased sensory awareness
 3. Lethargy
 4. Tachypnea
 5. Raised tail head
 6. Goose-stepping, stiff gait
 7. Synchronous diaphragmatic flutter
 8. Sweating laryngospasm
 9. Salivation
 10. Recumbency (if not treated)
 11. In mares it occurs 2 weeks before foaling, 10 to 80 days after foaling, or 1 to 2 days after weaning
 C. Clinical pathology
 1. Serum total calcium concentration
 a. tCa ~ 8 mg/dL; hyperexcitable
 b. tCa 5-8 mg/dL; tetany and incoordination
 c. tCa < 5 mg/dL; stupor and recumbency
 2. Serum total magnesium levels are usually low
 D. Differential diagnoses
 1. GI disorders
 2. Blister beetle toxicosis
 3. Transport tetany
 4. Athletic endurance
 5. Confinement + high grain ration
 E. Treatment: 500 mL of Cal-Dex solution, IV slowly
XV. Aortic thrombosis
 A. Clinical signs
 1. Vague hindlimb lameness
 2. Heavy sweating after exercise
 3. Cool pelvic limbs
 B. Diagnosis
 1. Rectal palpation
 2. Ultrasound
 C. Prognosis is grave
 D. Treat with heparin, aspirin

39 CHAPTER

Nutrition

Rebecca S. McConnico

BASIC BACKGROUND REGARDING EQUINE NUTRITION

I. Nonruminant herbivore
II. Hindgut fermenter
III. Horses can utilize high-fiber roughages as a source of nutrition, for example, grass or leguminous hays
IV. Horses can utilize high-quality concentrate feeds as well
V. Because horses are marketed or enjoyed as athletes, many nutritional strategies target their athleticism

BASIC EQUINE GASTROINTESTINAL ANATOMY RELATED TO NUTRITION

I. Mouth
 A. Equine upper lip is used for prehending food (gathering food bolus, grass, or grain)
 B. Upper incisors are used for cropping grass from pasture or hay portion
 C. Molars are important for grinding the feedstuffs (cracks fibrous feed coats)
 D. Muscles face, tongue, and jaws are used for chewing and masticating a food bolus within the oropharynx
 E. Cranial nerve (CN) V (trigeminal nerve) innervates the muscles of mastication
 F. *Ensalivation* is the process of moistening the food in the oropharynx
 G. Saliva production per horse in 24 hours + ~ 5-6 L/100 kg body weight
 H. The food bolus is swallowed via innervation of CN IX, X, and XII (glossopharyngeal, vagus, and hypoglossal)
 J. Dysfunctions in swallowing can result in two major complications
 K. Esophageal obstruction (also known as "choke")
 L. Tracheal aspiration can lead to aspiration pneumonia; aspiration pneumonia can lead to serious life-threatening disease if not treated appropriately
 M. Injury or disease of any of these structures can affect the horse's ability to gather or use feed
II. Stomach
 A. Small size reflects evolution of the horse as a nibbler (eats continually)
 B. Holds ~8 L and makes up ~8% of the total size of the digestive tract
 C. Relative rate of feed passage in equine stomach is rapid
 D. Small amount of enzymatic and microbial digestion begins in the equine stomach
III. Small intestine
 A. Primary site of enzymatic digestion, especially when diets high in concentrate are fed
 B. Proteins (polypeptides)
 1. Broken down by nonspecific oligopeptidases (brush border enzymes)
 2. Individual amino acids and dipeptides are absorbed
 3. Some via pancreatic enzymes
 4. Brush-border enzymes
 5. Requires sodium as cotransporter
 C. Carbohydrate digestion: Specific enzymes
 1. Sucrase, lactase, maltase
 2. Require sodium as transporter
 3. Pancreatic amylase: Hydrolyzes starch into disaccarides and trisaccharides for absorption
 D. Fats are emulsified in the small intestine and require pancreatic and biliary secretions
 1. Pancreatic lipase + triglycerides yield β-monoglycerides and free fatty acids, which are solubilized by bile salts and taken up by the enterocyte into the lymphatics
 2. Bile salts are taken up by active transport back to the liver (ileum)
 3. Fatty acids are absorbed as micelles, then re-esterified to triglycerides within the enterocyte
 4. Released as chylomicrons into lymphatics as complexes of cholesterol, phospholipids, and a protein coat
 5. Entire process is passive
 E. Absorption of water occurs in the equine small intestine
 1. Via diffusion down concentration gradient
 2. Between cell tight junctions
 3. Through cells → apical to basolateral
 4. Can also go from plasma to lumen
 F. Sodium and water transport occurs in the equine small intestine
 1. Chloride transport is via passive transport through the tight junction
 2. Is carrier-mediated, electrically neutral, with Na+ cotransport
 G. Bicarbonate transport (HCO3-) – is dumped from liver and pancreas directly into the intestine:

$$H^+ + HCO_3\text{-} \rightarrow H_2CO3 \rightarrow CO_2 + H_20$$

CO_2 equilibrates within epithelial cells and venous blood

H. H^+ secreted into lumen for Na <—> H exchange $NaHCO_3$ co-transport: Apical membrane

IV. Large intestine
- A. Anatomic components include the cecum, large colon, transverse colon, small colon, and rectum
- B. Primary digestive function is production of volatile fatty acids (VFA)
- C. Other LI digestive function
 1. Soluble carbohydrate (CHO)
 2. Insoluble CHO
 3. Absorption of VFA
 4. Absorption of H_2O and electrolytes along with VFA
 5. Maintenance of luminal pH (6.8-7.2) and osmolality
 6. Protein digestion
- D. LI – Transit times
 1. Liquids
 - a. About 6 to 24 hours to appear in the feces (12 to 24 hours is realistic)
 - b. Most liquid has passed in about 3 days
 - c. 100% fluid is gone in 9 days
 - d. Small colon does reabsorb fluid
 2. Particulates
 - a. 24 hours to appear in feces
 - b. 40% of 2-cm particles have passed in 10 days
- E. Differences in lower intestine vs. small intestine
 1. Lower intestine has no mucosal enzymes
 2. Na^+-H^+ exchange diffusion is less pronounced
 3. No active transport mechanisms for glucose, amino acids, or absorption of B vitamins
 4. Presence of microbial population
 5. Digestion of CHO and proteins is via microbial fermentation
 6. Tight junction permeability is less
 7. Net secretion of K^+ occurs
- F. Fermentation
 1. Primary digestive processes in cecum and colon are fermentative
 2. No specific digestive enzymes either secreted or bound to cells
 3. Bacterial populations similar in function to those in the rumen
 4. Mostly anaerobes, with some aerobes and ciliates or flagellates
 5. Products are also similar to rumen products
 6. Production of VFAs: Acetic acid → propionic acid → butyric acid
 7. VFA absorbed from the lumen → provide 75% of energy requirements of adult horses
 8. Large instestine is capable of producing lactic acid if appropriate conditions exist
 9. Production of VFAs tends to make cecum and ventral colon slightly acidic
 10. Because of the slower overall rate of fermentation, drastic pH drops resulting from overproduction are rare
 11. Gases produced = methane and CO_2
 12. Substrates are different from those presented to rumen
 - a. Most simple carbohydrates, proteins, and fats are already gone (absorbed in small intestine)
 - b. Fermentation substrate is complex carbohydrates of plant origin
 - c. Starches digested in the small intestine
 - d. Cellulose, lignin available to colon bacteria
- G. Nutrient absorption: Large intestine
 1. Absorption of VFAs uses a similar mechanism as the rumen
 - a. Ion trapping helps absorption
 - b. Colon pH and tissue pH usually quite close, so overall movement is slower
 - c. Most absorption occurs in cecum and ventral colon
 - d. Distal colon usually slightly basic because of the secretion of bicarbonate in exchange for chloride
 - e. VFA absorption: Na-independent (diffusion via undissociated acid)
- H. Enterosystemic cycle (small intestine and large intestine)
 1. There is net movement of fluid into and out of the gut lumen every 24 hours
 2. The sum total of the secretions involved in enterosystemic cycling = ~80 L per adult horse, or = 1.5× total extracellular fluid volume
- I. Transport of water and electrolytes: Large intestine
 1. Electrolyte: Composition of large intestine contents
 - a. Cl- from stomach→ reabsorbed in small intestine
 - b. HCO_3- increases in small intestine → presented to large intestine
 - c. HCO_3- is buffer for VFAs in large intestine (cecum)
 - d. Both VFA production and $HCO3^-$ are necessary for neutralization of large intestine contents
- J. Large intestine: Mixing
 1. Contractions originate in pelvic flexure
 2. Pelvic flexure contractions are bidirectional
 3. Feed is retained in ventral colon for 2 to 7 days, then in dorsal colon for 2 to 10 days
 4. Colonic motility
 5. Cecal pacemakers in the body of the cecum are bidirectional
 6. Primary colonic pacemakers are located in anatomically analogous locations as in the simple colon
 7. Beginning of the colon (right ventral)
 8. Middle of the colon (pelvic flexure)

GENERAL EQUINE NUTRITION

I. Clean water must be available at all times

II. Horse should drink about 25 to 75 mL/100 lb of body weight per day

III. Do not allow a horse to drink a large volume of water when it is hot. This has been associated with colic, diarrhea, and laminitis

IV. Forage-fiber required
- A. Fiber is needed for energy for microbes
- B. Source of energy for the horse
- C. Promotes motility and function and helps prevent too rapid intake of readily digested carbohydrates

V. Forage requirement
 A. 1 lb forage dry matters per 100 lb body weight
 B. 10 lb forage per day
VI. Inadequate forage
 A. Leads to boredom (eating time)
 B. Risk of diarrhea, colic, laminitis
 C. Eating wood, tail chasing, mane chewing
 D. Wood chewing: Facility damage
 E. Wood splinters in oral cavity
 F. Intestinal obstruction
VII. Grain feeding is not always necessary but is required when:
 A. Nutrients are needed that are not provided by forage
 1. Mixed sweet feeds (oats, corn, barley, soy protein, etc. with molasses)
 2. Oats (crimped or whole)
 3. Commercial equine pelleted feeds
 B. Growth, lactation, or increased training or use
 C. Forage is unavailable or poor quality
 D. Desired for treats, training behavior modification.
 E. Grain feeding may cause only diarrhea, colic, laminitis, exertional myopathy, hyperactivity, obesity. The rule of thumb is that a horse should not ingest more than a maximum of 50% grain mix in diet of total dry weight
VIII. General rule for feeding horses
 A. Hay should be available at all times; grasshay (Bermuda or brohm grass), timothy, alfalfa
 B. Good-quality pasture is superior for forage feeding
 C. 50% to 70% of time grazing on pasture when full-time pasture
 D. Maximum = 0.9 lb/100 lb body weight or for an average 1000 lb horse = 9-10 lb daily; divide twice daily (three times daily is even better)
 E. Feed at same time every day
 F. Feed equally divided meals
 G. Feed working, growing, lactating horses more grain. 3 × daily (2-3 % body weight daily) = 20 lb/day
 H. Owners should not feed grain 4 to 5 hours before exercise
IX. Overfeeding leads to fat horses and can be due to inadequate use or overfeeding show horses for the perceived chance of winning (fatter horses often fare better in the show ring) pecking order
X. Thin horses can be caused by the following:
 A. Poor or inadequate hay
 B. Dental problems
 C. Excess endoparasites or exoparasites
 D. High-energy demands
 E. Prolonged hot, humid weather
 F. Chronic disease

VITAMINS AND MINERALS

I. National Research Council requirements
 A. Vitamins A, D, E
 B. Riboflavin
 C. Thiamine
 D. Vitamin E and thiamine both have increased requirements for working horses
 E. Minerals such as electrolytes can be readily lost in sweat: Sodium, potassium, and chloride
 F. Free-choice salt or salt mineral blocks are recommended for working horses
 G. Alfalfa hay is a good source of potassium

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine*, 2nd ed. St Louis, 2004, Saunders.

Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine*, 6th ed. St Louis, 2009, Saunders.

40 CHAPTER

Oncology

Yvonne A. Elce

BASIC PRINCIPLES

I. Neoplasia can occur in horses of any age, breed, or sex. The geriatric population of horses is increasing with improvements in management and veterinary care, so the equine veterinarian must attempt to keep up with the rapidly advancing field of equine oncology through continuing education
II. Definitive diagnosis of tumors is through histopathology and is highly recommended in all instances of neoplasia as the treatment and prognosis vary widely depending on the type of tumor
III. Most common tumors seen by veterinarians in horses are skin tumors (sarcoids, melanomas, squamous cell carcinomas), tumors of the sinuses and nasal passages, and lymphosarcoma
IV. Health management and regular examinations will enable early detection, which is crucial to improving the prognosis
V. Treatment should be undertaken only after discussions with the owner involving the prognosis, quality of life, and economic issues surrounding the decision

TUMORS OF THE SKIN AND UNDERLYING TISSUES

I. Most common form of tumor in the horse
II. Not confined to geriatric horses
III. Tumor types
 A. Most common are sarcoids, squamous cell carcinoma, and melanomas
 B. Less common are lymphosarcoma, mast cell tumors, basal cell tumors, and hemangiomas
IV. Common differentials for skin tumors include fungal lesions, cutaneous habronemiasis, pythiosis, phycomycosis, exuberant granulation tissue, and varying types of tumors.
V. Sarcoids
 A. Causes (Figure 40-1)
 1. Related to interaction between genetics and infection with bovine papillomavirus
 2. Found on limbs, ears, eyelids, head, and trunk but can occur anywhere
 3. Often found in areas of repetitive trauma or injury
 4. Four main types: Occult (flat, thickened areas of skin lacking hair), verrucous (warty and small), nodular (under-the-skin small nodules), and fibroblastic (aggressive, resemble exuberant granulation tissue)
 5. Fibroblastic types are locally invasive and grow rapidly; no type is metastatic
 B. Signalment
 1. Breed predilections in quarter horses, Appaloosas, and Arabians; not commonly found in standardbreds
 2. Generally in younger horses 1 to 6+ years of age
 3. No sex predilection
 C. Clinical signs
 1. Depends on type of sarcoid; noticed usually as small area of abnormal skin
 2. Fibroblastic types found in areas of previous trauma or wounds
 3. Do not interfere with function unless grow large and impinge on adjacent structures such as the eye, joints, or tendons
 D. Diagnosis
 1. It is not recommended to biopsy occult, small verrucous and nodular sarcoids as trauma may transform them into fibroblastic types
 2. However, definitive diagnosis is based on histopathology
 E. Treatment
 1. Many different treatments available
 2. Surgical excision as the sole treatment has a high rate of recurrence (50%)



Figure 40-1 Equine sarcoid. Multiple nodular lesions in medial canthal area. (From Scott DW, Miller WH. *Equine Dermatology*. St Louis, 2003, Saunders.)

3. Other treatments include cryotherapy, laser-assisted excision and ablation, intralesional cisplatin or 5-fluorouracil, radiation therapy, hyperthermia
4. Many commercial topical preparations available usually containing caustic substances to cause sloughing of the sarcoid
5. Injections of EqStim or bacille Calmette-Guérin (BCG) can be given to stimulate the immune system to reject the sarcoid. There have been reports of anaphylaxis after multiple BCG injections, so it is recommended to pretreat with antiinflammatory drugs.

VI. Squamous cell carcinoma
- A. Causes
 1. Most common tumor of the eye and external genitalia
 2. Also found in the stomach, oral pharynx/larynx, and bladder
 3. Light-colored breeds and nonpigmented areas of skin are predisposed because solar radiation plays a role in carcinogenesis. Also local carcinogens (smegma accumulations in the sheath) may be important
 4. Locally invasive and can become metastatic
 5. Can be ulcerative or proliferative lesions
- B. Signalment
 1. Common in older horses
 2. Draft horses, Appaloosas, Arabians, paint, and pinto horses are predisposed (light- colored horses)
- C. Clinical signs
 1. Depends on location of tumor
 2. Foul smell common with all locations (oral, genital)
 3. Ocular tumors usually start as small white lesions on the eye or adnexal structures with blood-stained tears
 4. Common with genital tumors to have discharge or bleeding, dysuria, preputial edema
- D. Diagnosis is through histopathology or cytology (biopsy, fine-needle aspirate, impression smear)
- E. Treatment
 1. Many treatments available
 2. Surgical excision is best combined with adjunctive therapy (radiation or local chemotherapy)
 3. Local chemotherapy can be performed with intralesional 5-fluorouracil (5-FU) or cisplatin
 4. In addition, 5-FU cream can be applied every 1 to 2 weeks as a thin coating until resolution
 5. Other treatments include cryotherapy, hyperthermia, radiation therapy
 6. New reports of successful resolution with administration of systemic nonsteroidal antiinflammatory drugs (NSAIDs), particularly piroxicam at 0.2 mg/kg once daily orally. Squamous cell carcinomas produce cyclo-oxygenase-2 (COX-2), which aids in tumor growth and metastasis; treatment with COX inhibitors can cause tumor regression. Need to monitor for NSAID side effects (renal damage, ulcers in the stomach or colon)
- F. Prognosis
 1. Good if tumors are diagnosed and treated when they are small and before local spread or metastasis
 2. Improved with use of ancillary therapies such as radiation and chemotherapy
 3. Large invasive tumors often involve local lymph nodes and should provoke examinations for metastases, which decrease the prognosis significantly
 4. Regular examinations of older horses (sheath cleanings and inspection of external genitalia) are recommended to aid in early detection
 5. Recommend reducing exposure to solar radiation of light-colored horses with areas of nonpigmented skin through nighttime turnout routines or solar radiation–blocking blankets

VII. Melanomas
- A. Cause
 1. Unknown
 2. May be due to disturbed melanin metabolism or production of new melanoblasts
 3. Single nodules or coalescing nodules in or under the skin
 4. Commonly slow growing and invade locally but may become fast-growing, malignant, and metastasize to internal organs (lungs, GI tract, spleen)
 5. Most tumors produce melanin but particularly in non-gray horses may have amelanotic melanomas. Amelanotic melanomas in colored horses are usually aggressive and metastasize
- B. Signalment
 1. Older (15 years+) gray horses are most at risk (70% to 80% of older gray horses develop melanomas)
 2. Melanomas can develop in horses of any color but are more often malignant in non-gray horses
 3. No sex predilection
- C. Clinical signs
 1. Formation of masses under the skin or as dark black masses when the skin has ulcerated
 2. Common areas include under the tail, perineal region, and external genitalia
 3. Other areas include the neck, the parotid salivary gland, the head, limbs, and guttural pouches
 4. Can develop difficulty defecating, urinating, or breathing, depending on the location of the tumor as the result of a local mass effect but often not clinically significant early
 5. Signs of metastasis relate to organs affected (e.g., weight loss, respiratory signs)
- D. Diagnosis
 1. Can be based on gross appearance and common signalment
 2. Can be confirmed by cytology or histology

E. Treatment
 1. Often left untreated if clinically insignificant and growing very slowly
 2. However, best treated when masses are small
 3. Treatments consist of surgical excision (it used to be thought that incomplete excision would result in malignant transformation but recently reports show success of local excision without large margins)
 4. Other treatments include intralesional cisplatin and cryotherapy
 5. Oral cimetidine can be administered; reports of success are variable. Cimetidine is a histamine receptor agonist. It blocks the binding of histamine, which stimulates T-suppressor cell inhibition of cell-mediated and humoral responses. By blocking this, cimetidine is thought to enhance the immune system's ability to respond to the tumors
 6. Autogenous vaccines are under development and have variable success

F. Prognosis
 1. Close monitoring of all older gray horses is recommended
 2. Treatment of lesions is recommended before the lesions become too large and invasive but might not be necessary for small, clinically insignificant lesions
 3. Gray horses with large, rapidly growing melanomas and non-gray horses with melanomas should be examined closely for metastases, which give a very poor prognosis

VIII. Uncommon skin tumors

A. Basal cell tumors
 1. Benign cutaneous neoplasms with no known sex, age, or breed predilection
 2. Appear as raised nodular and occasionally ulcerated lesions and have been reported on the limbs, trunk, neck, tail, and lips
 3. Excisional biopsy is curative

B. Mast cell tumors
 1. Reported cases of congenital and multifocal form but most commonly as solitary nodules in older horses (average age, 7 years)
 2. Males are more commonly affected than females
 3. Usually solitary dermal and subcutaneous nodules consisting of mast cells and often dystrophic mineralization
 4. The head, neck, and trunk as well as lower limbs are common locations
 5. Lower limb nodules are often close to joints, without lameness or pain
 6. Surgical excision, even if incomplete, is often curative

C. Hemangiomas
 1. Commonly benign in young horses younger than 1 year or malignant in older horses (8+ years)
 2. Proliferative, solitary lesions that often bleed easily or ulcerate and occur most commonly on the lower limbs. Occasionally grow next to and involve joints
 3. Surgical excision is treatment of choice and is often successful
 4. If recur rapidly and aggressively, prognosis becomes poor
 5. Disseminated hemangiosarcoma has been reported to occur in horses but is rare

D. Lymphoma or lymphosarcoma: Covered in detail below; cutaneous lesions can be the primary tumor or secondary to another form.

TUMORS OF THE SKULL AND SINUSES

Many different tumors can occur in the head region of the horse:

I. Sinuses and nasal passages

A. Tumors can occur in horses of any age, and definitive diagnosis is required to determine the correct treatment and prognosis

B. Tumors in the sinuses must be distinguished from cysts, sinusitis, and tooth root abscesses

C. Broad variety of tumors occur, including squamous cell carcinoma, adenocarcinoma, dental origin tumors (odontoma, cementoma, ameloblastomas), lymphoma or lymphosarcoma, ossifying fibromas, fibromas or fibrosarcomas, osteomas or osteosarcoma, and others

D. Clinical signs of sinus tumors include facial swelling, nasal discharge, decreased airflow through one or both nostrils, decreased appetite, and attitude

E. Diagnosis is made through radiographs, computed tomography, endoscopy, and biopsy (biopsy can be obtained by an excisional biopsy through a sinus flap at a surgical facility or obtaining a small biopsy through a trephine hole into the sinus)

F. Treatment depends on the tumor and location. Options include radiation therapy and surgical excision if possible

G. Prognosis: Solid noninvasive tumors have an improved prognosis (fibromas, osteomas) compared with invasive tumors, but all require surgery, radiation therapy, or both

II. Mandible and maxilla

A. A variety of tumors have been reported in the mandible and maxilla

B. Juvenile ossifying fibromas have been reported in young horses (i.e., younger than 1 year) with a slowly enlarging mass involving the rostral mandible. Radiographs reveal proliferative bone, and a surgical hemimandibulectomy is curative

C. Other tumors occur in older horses as they do in the sinuses. Diagnosis and treatment should be based on biopsy and histopathological diagnosis

III. Larynx-pharynx and guttural pouches

A. Squamous cell carcinomas and melanomas are reported the most commonly from these locations

B. Clinical signs include palpable swellings, foul odor to the breath, and difficulty with eating and swallowing

C. Often difficult to access and completely excise surgically, so treatments frequently are limited to chemotherapy and radiation
D. Other differentials include tumors of other types and foreign-body reactions (grass awns or splinters in the oral cavity)
E. Sarcoids do occur commonly at lip margins as well

TUMORS OF THE ENDOCRINE AND HEMOLYMPHATIC SYSTEM

I. Lymphoma-lymphosarcoma
A. Causes
1. Four anatomic forms described: Generalized, alimentary, mediastinal, and cutaneous or extranodal
2. Forms commonly overlap in the clinical situation
3. Unknown cause: T- and B-cell lines have been involved
4. The generalized or multicentric form is the most common. It involves peripheral and internal lymph nodes and organs. Clinical signs are related to which organs are involved. This form often has circulating neoplastic lymphocytes
5. The alimentary form is often acute with rapid deterioration. Can be found in younger horses (2 to 5 years of age) and commonly presents with signs of weight loss, colic, diarrhea, ventral edema, and fever
6. The mediastinal form affects the mediastinal lymph nodes and causes compression of intrathoracic structures. It occurs more commonly in adult horses. Clinical signs are referable to the thorax with cough, pleural effusion, tachycardia, and tachypnea. The paraneoplastic sign of hypercalcemia has been reported with this form. Pleural effusion may show neoplastic cells on cytology for diagnosis
7. The extranodal form can occur as cutaneous lesions or as lesions involving the eyes, upper respiratory tract, or central nervous system. The cutaneous lesions are nonpainful dermal or subdermal masses occurring either singly or as multiple lesions
B. Signalment
1. No sex or breed disposition
2. Reported in horses of all ages, although 5 to 10+ years most common
C. Clinical signs
1. Relate to organ or organs affected
2. Cutaneous form usually and dermal lesions; may be ulcerated with subcutaneous infiltrate or multiple subcutaneous nodules
3. Intestinal form presents with weight loss (malabsorption), diarrhea, and colic
4. Other clinical signs include fever, regional lymphadenopathy, and ventral edema
5. Respiratory signs if thoracic neoplasia is present: Tachypnea, dyspnea, pleural effusion, and coughing
6. Occasional involvement of nasal passages, sinuses, or oral pharynx
D. Diagnosis
1. Made on the basis of biopsy of enlarged lymph node or affected organ (intestine, subcutaneous nodule, pleural effusion)
2. Hematology can be variable, although hypercalcemia has been reported
3. Normal "reactive" lymphocytes may be hard to distinguish from neoplastic cells
E. Treatment
1. The local cutaneous form may be responsive to surgical excision, local and systemic administration of steroids, immunomodulators, and oral progesterones. It has been reported to recur more aggressively if therapy is stopped too soon
2. Intestinal lymphosarcoma can be surgically excised depending on the location and extent of the tumor
3. Cytotoxic drugs, immunomodulators, and corticosteroids can be tried with systemic disease
F. Prognosis
1. Generally poor to grave for survival
2. Local forms (intestinal or cutaneous) that can be treated with surgical excision and follow-up systemic therapy yield the best prognosis

II. Thyroid tumors
A. Cause
1. Adenomas, adenocarcinomas, and medullary carcinomas can all occur
2. Main differential is benign goiter or cysts
3. Adenomas are by far the most common tumor
4. Very rarely metastasize but have been reported to do so
5. Unilateral
B. Signalment
1. Occurs more commonly in older horses
2. Lightbreeds are reportedly more commonly affected than draft breeds
C. Clinical signs
1. Most tumors are nonproductive, and clinical signs may be solely a unilateral, palpable swelling
2. Tumors can become large enough to cause tracheal deviation and respiratory difficulty or interfere with swallowing (constant "gulping" has been reported)
3. Thyroid dysfunction can be evident if the tumor is productive, either hypothyroidism or hyperthyroidism
D. Treatment
1. Warranted only if tumor is productive or interfering with normal function
2. Surgical excision is curative
3. Complications associated with surgical excision include laryngeal hemiplegia, seroma, infection, or hemorrhage (parathyroids not connected to thyroids, so calcium hemostasis is not affected)

4. Excision is unilateral, so postoperative thyroid function is usually adequate and supplementation unnecessary

III. Adrenal glands
 A. Uncommon tumors: Functional pheochromocytomas have been reported in older horses with no breed or sex predilection
 B. Clinical signs often include episodes of sweating, anxiety, tachycardia, tachypnea, and muscle fasciculations often mistaken for colic
 C. Diagnosis is often through exclusion of other problems and typical presentation. Azotemia, metabolic acidosis, hyperkalemia, and hyperglycemia are common serum biochemical abnormalities
 D. Treatment is not commonly recommended as surgical excision is extremely difficult

IV. Myeloid leukemias
 A. Rarely reported in the horse
 B. Myeloid leukemias are characterized by the unregulated proliferation of a bone marrow–derived blood cell line causing loss of normal blood components
 C. Clinical signs relate to the loss of normal blood components, and diagnosis is made on laboratory examination or bone marrow biopsy
 D. Extremely poor prognosis for life
 E. Invasion of the bone marrow has also been reported by metastasis from other tumors
 1. Plasma cell myelomas have been reported either as a solitary extramedullary tumor or in the bone marrow (multiple myeloma) with a very poor prognosis
 2. Diagnosis is again through laboratory examination of the blood or bone marrow biopsy

V. Spleen
 A. Can be involved in metastases from other tumors, especially melanomas
 B. Rarely is the site of a primary tumor

VI. Liver
 A. Rarely can have primary liver tumors (cholangiosarcoma, hepatocellular carcinoma)
 B. Can be a site for metastases of other tumors such as lymphosarcoma
 C. Clinical signs relate to disorder of liver function
 D. Diagnosis would be obtained through liver ultrasound, function testing, and biopsy

GASTROINTESTINAL (GI) TUMORS

I. Stomach
 A. Squamous cell carcinomas occur in the stomach of older horses
 B. Clinical signs include weight loss, inappetance, and colic
 C. Diagnosis is through endoscopy and biopsy. Abdominal ultrasound can be helpful
 D. Treatments are limited to piroxicam or other NSAIDs; efficacy is unknown
 E. Horses must be monitored for side effects of NSAIDs, and prognosis is extremely grave

II. Intestine
 A. Lymphosarcoma can occur as detailed previously
 B. Mesenteric lymph nodes can be involved in metastases from other tumors, such as melanomas and squamous cell carcinoma

UROGENITAL TUMORS

I. External genitalia commonly affected by skin tumors detailed previously

II. Bladder
 A. Squamous cell carcinoma is the most common neoplasm of the equine bladder
 B. Transitional cell carcinoma, leiomyosarcoma, and lymphosarcoma have been reported to occur as well
 C. There are no reported breed or sex predispositions, and older horses are most commonly affected
 D. Clinical signs include hematuria, and diagnosis can be made using rectal palpation, ultrasound, endoscopy and biopsy, and urine cytology
 E. Prognosis is poor
 F. Treatments can include partial resection, instilling chemotherapeutic agents such as 5-FU and systemic administration of piroxicam or other NSAIDs

III. Kidneys
 A. Renal tumors are uncommon and include renal cell carcinoma or adenocarcinoma, nephroblastomas, and adenomas
 B. Renal cell carcinomas have been reported in horses aged 4 to 16 years of age with no breed or sex predisposition
 C. Common clinical signs include weight loss, hematuria, colic, and diarrhea
 D. Diagnosis is through ultrasound, urine cytology, peritoneal fluid cytology, and percutaneous biopsy
 E. Prognosis is very poor because of the relative difficulty of surgical excision and frequent metastases
 F. The kidneys can also be a site for metastases from other tumors such as melanoma, squamous cell carcinoma, and lymphosarcoma

MUSCULOSKELETAL SYSTEM

I. Very rare to have primary bone or muscle tumors in horses

II. Primary muscle tumors (rhabdomyosarcomas) have been described as hard, spherical masses deep in the muscle, and certainly other tumors can occur (e.g., hemangiosarcoma, fibroma or fibrosarcoma, lipomas)

III. The muscle can be involved in local invasion from, or metastases from, tumors such as squamous cell carcinomas, and melanomas

IV. Joints and tendons can also be affected by invasion or compression from skin tumors

THORACIC NEOPLASIA

I. The respiratory system can be involved in lymphosarcoma and disseminated hemangiosarcoma as well as metastases from other tumors such as melanomas and squamous cell carcinomas
II. Other primary thoracic tumors are very rare

Supplemental Reading

Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.
Foy JM, Rashmir-Raven AM, Brashier MK. Common equine skin tumors. *Compendium* 2002;24:242-253.
May KA, Moll HD, Lucroy MD. Recognizing tumors of the equine external genitalia. *Compendium* 2002;24:970-976.
Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine*, 2nd ed. St Louis, 2004, Saunders.
Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine*, 6th ed. St Louis, 2009, Saunders.

41 CHAPTER

Ophthalmology

Rebecca S. McConnico

CORNEAL DISEASE: ULCERATION

I. History: No age, breed, or sex predilection
II. Clinical signs
 A. Blepharospasm
 B. Epiphora
 C. Photophobia
 D. Head shy: Difficult to examine the eye
III. Causes
 A. Mechanical injuries
 B. Entropion (foals)
 C. Toxic causes
 D. Infectious
 E. Chemical insult
 F. Decreased tear production
IV. Diagnostic plan
 A. Fluorescein-dye staining of the cornea
 1. Application of stain requires appropriate restraint
 2. Superficial damage will have minimal uptake, whereas more significant deficit will have bright green uptake at the site
 B. Culture and cytology
 C. Corneal scraping for Gram staining and culture and microscopy to evaluate cytologic makeup and morphology
V. Therapeutic plan
 A. Pharmacologic therapy
 1. Antibiotics
 a. Essential for treatment even if it is not yet infected
 b. Broad-spectrum antimicrobial therapy (bacitracin, neomycin, polymyxin B, or products with gentamicin or chloramphenicol)
 2. Antifungals for mycotic infections
 B. Remove any mechanical causes (exposure, drying)
 C. Debridement and surgery
 1. Remove necrotic tissue
 2. If desmetocoele is present, perforations is imminent
 D. Prognosis: Dependent on rapidity of diagnosis, successful management, owner compliance, and organisms involved

CONJUNCTIVAL DISEASE: KERATOCONJUNCTIVITIS

I. Clinical signs
 A. Lacrimation
 B. Blepharospasm
II. Causes
 A. Viral
 1. Equine herpes
 2. Equine arteritis virus
 B. Others
III. Treatment: Topical antimicrobial therapy

OCULAR TRAUMA

I. Blunt trauma or perforating injuries
II. Clinical Signs: Chemosis, epiphora, blepharospasm
III. Diagnosis
 A. Visual inspection: Requires restraint
 B. Consensual papillary response
IV. Treatment of lacerations
 A. Lid lacerations should be sutured
 B. Conjunctival lacerations: Heal by second intention
 C. Treat as a corneal ulcer with topical antibiotics after primary closure (if there is full-thickness injury)
 D. Hyphema: Treat with corticosteroids and mydriatics
 E. Do not use corticosteroids if there is corneal abrasion or laceration
 F. Systemic antiinflammatories

EQUINE RECURRENT UVEITIS (MOON BLINDNESS)

I. History
 A. Repeated bouts of eye pain
 B. Leading cause of blindness
II. Clinical signs (Figure 41-1)
 A. Injected conjunctiva (circumferentially)
 B. Corneal edema
 C. Aqueous flair (cells or fibrin in the anterior chamber)
 D. Miosis
 E. Neovascularization
 F. Photophobia and epiphora
 G. Hypotonia (decreased pressure)
 H. Hypopyon after several days
 I. Predisposes to cataracts
III. Causes
 A. Microbial pathogens
 B. *Leptospirosis*
 C. *Brucella*
 D. *Streptococcus*
 E. *Onchacerca cervicalis*

IV. Pathogenesis: Inflammatory response → disrupts ciliary body → leakage of protein and fibrin
V. Diagnosis
 A. History
 B. Paired titers to determine whether *Leptospirosis* or *Brucella* organisms are associated in the case



Figure 41-1 A horse experiencing a classic acute inflammatory episode of equine recurrent uveitis. Periocular swelling, lacrimation, corneal edema, and blepharospasm are visible. (From Gilger B. *Equine Ophthalmology*. Philadelphia, 2005, Saunders.)

VI. Treatment
 A. Atropine
 B. Corticosteroids
 C. Topical nonsteroidal antiinflammatory drugs
 D. Microfilaricide therapy
VII. Prevention: Considered an unsoundness

OTHER DISEASES

I. Periorbital disease (covered in Chapter 33, Dermatology)
 A. Sarcoids
 B. Squamous cell carcinoma (covered in Chapter 40, Oncology and Chapter 33, Dermatology)
 C. Ulcerative disease (covered in Chapter 33, Dermatology)
II. Congenital ocular disease
 A. Dermoids affect eyelid margin: Surgical removal may be indicated
 B. Congenital blockage of the nasolacrimal duct: Persistent epiphora
 C. Cataracts: Usually affect both lenses
III. Manifestations of systemic disease
 A. Exophthalmus
 B. Horner syndrome
 C. Blindness: Trauma, other systemic disease

Supplemental Reading

Reed S, Bayly W, McEachern RB, and Sellon D. *Equine Internal Medicine,* 2nd ed., St Louis, 2003, Saunders.
Robinson NE, Sprayberry KA. C*urrent Therapy in Equine Medicine,* 6th ed., St Louis, 2009, Saunders.

42 CHAPTER

Orthopedic Disorders

Rebecca S. McConnico

Please refer to Chapter 47 for further review of equine orthopedic diseases.

THRUSH

I. Affects the central and lateral sulci of the frog (Figure 42-1)
II. Dermatitis of the frog
III. Occurs in horses kept in confinement in unsanitary conditions
IV. Clinical findings
 A. Soft, spongy, flaky frog (advanced cases)
 B. Fetid odor
 C. In some cases, lameness results
 D. Advanced cases may involve inflammation of the coronary band
 E. Discharge of pus from fissures in the coronary band may exist
V. Causes
 A. *Fusobacterium necrophorum* possibly plays a role in the pathogenesis
 B. Unhygienic conditions, loafing in wet or unhygienic conditions
 C. Poor foot care
 D. Lameness leads to decreased exercise, causing further predisposition to thrush
VI. Diagnosis is based on clinical findings
VII. Treatment
 A. Pare out foot and remove dead or necrotic frog and sole
 B. Drying and antiseptic products to include copper sulfate, iodines
 C. If sensitive laminae become exposed, bandaging may be necessary
VIII. Prevention: Hygiene, keep feet picked out, dry bedding and pasture

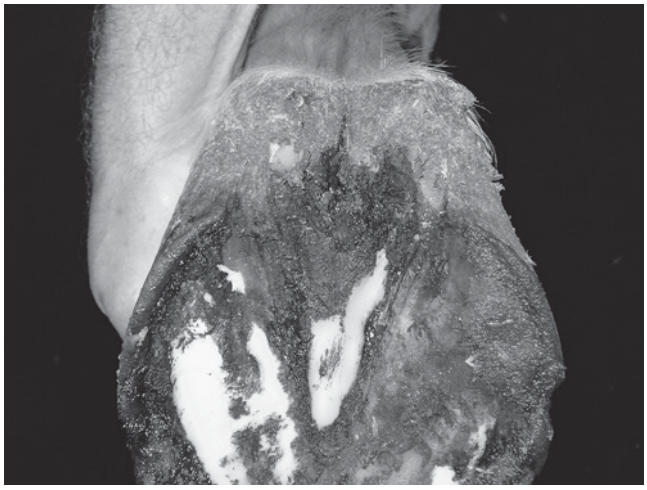


Figure 42-1 Typical case of thrush affecting most of the frog. (From Floyd A, Mansmann R. *Equine Podiatry*. St Louis, 2007, Saunders.)

LAMINITIS

I. Occurs in ponies and horses (may be more common in ponies)
II. Inflammation of the sensitive lamina in foot
III. Clinical signs
 A. Shifting leg lameness
 B. Short strided walk
 C. Progressive cases spend a lot of time in recumbency
 D. Bounding digital pulses
 E. Increased heat to the hoof walls
 F. Pain on hoof tester pressure
 G. Heel-to-toe placement
IV. Chronic laminitis
 A. May be more common in overweight horses
 B. Recurrent episodes of lameness
 C. Hoof wall rings
 D. Dropped or flattened sole
 E. Long toe
V. Lameness grading system
 A. Obel grade 1: No lameness except for a short stilted gait
 B. Obel grade 2: Discomfort and lameness at the walk; can lift each forefoot without difficulty
 C. Obel grade 3: Reluctance to move and resistance to lifting forefeet
 D. Obel grade 4: Planted feet; difficult to get the horse to move
 E. Obel grade 5: Horse is recumbent
VI. Causes
 A. Systemic disease such as septicemia, endometritis, colitis (salmonellosis, clostridiosis)
 B. Carbohydrate overload
 C. Predisposing factors
 1. Excessive trauma, concussion of foot
 2. Excessive weight bearing

VII. Theories of pathogenesis
 A. Hemodynamic theory: Vasoconstriction within the digital circulation causes a decreased perfusion to the nutrient laminar capillaries, leading to ischemia, followed by painful reperfusion injury and enzyme damage. This damage may rapidly lead to tearing of the laminar bonds and displacement of the pedal bone away from the hoof wall
 B. Connective tissue theory: Degeneration of the connective tissue of the basement membrane mediated by activation of matrix metalloproteases is a primary event in acute laminitis
 C. Inflammation: Inflammatory cells and activation of a complex cascade of events cause extravasation and subsequent pathophysiology
VIII. Diagnosis
 A. Clinical signs and history
 B. Radiographs: Changes in the angulation of the distal pedal bone; thickening (suggestive of edema) between the hoof wall and the pedal bone
IX. Treatment
 A. Treat initiating cause
 B. Antiinflammatory therapy (nonsteroidal antiinflammatory drugs, such as phenylbutazone therapy)
 C. Frog support
 D. Additional therapy that has been suggested but is of questionable efficacy
 1. Acepromazine to restore digital blood flow
 2. Phenoxybenzamine for α-adrenergic antagonist
 3. Isoxuprine hydrochloride for digital blood flow
 4. Dimethyl sulfoxide as an antiinflammatory and free radical scavenger
 5. Sodium heparin to help prevent vascular thrombosis
 6. Lidocaine: Constant rate infusion
 E. Nerve blocks used to localize the pain to the feet
 F. Hoof trimming: Lower the heels and ease breakover of the toe
 G. Treatment for chronic laminitis
 1. Provide feed supplements that contain DL methionine, which restores disulfide bonds
 2. Hoof wall resection
X. Prevention: Dietary and health management

SECONDARY NUTRITIONAL HYPERPARATHYROIDISM (BIG HEAD, BRAN DISEASE)

I. Cause: Calcium deficiency relative to excess PO_4
II. Clinical and laboratory findings
 A. Bone pain
 B. Enlarged physes
 C. Osteodystrophy (big head)
 D. Serum calcium and PO_4 are normal
 E. Urinary PO_4 is elevated (fractional excretion of Ca is decreased; fractional excretion of PO_4 is increased
 F. Radiography: Bones of the head and neck show decreased radiopacity
III. Diagnosis: Nutritional secondary hyperparathyroidism
 A. Fractional clearance of Ca and PO_4
 1. Fx = urine e-/plasma e- $\times$ plasma Cr/urine Cr $\times$ 100%
 2. FCl Ca $>$ 2.5%
 3. FCl PO_4 $<$ 4%
 B. Parathyroid hormone levels (blood)
 C. Radiography: Decreased bone opacity
 D. Diet analysis: Ca:PO_4 ratio less than 1.5:1
IV. Vitamin D toxicosis
 A. Oversupplementation of vitamin D
 B. Ingestion of *Cestrum diurnum* (wild jasmine, day cestrum)
 C. Elevated serum Ca
 D. Serum PO_4 is normal

ANGULAR LIMB DEFORMITY

I. Occurs in foals of all breeds
II. Does not seem to be any higher incidence of the problem in colts compared with fillies
III. Foals can either be born with deviated limbs (congenital) or develop the problem later (acquired) during their first year of life, when rapid changes are occurring in the bone and joints
IV. Clinical signs (Figure 42-2)
 A. Lateral (outward) or medial (inward) deviation of a limb
 B. Carpus is most common joint affected
 C. Fetlock and tarsus can be affected
 D. Usually more than one leg involved
V. Pathology: Angular deformity of a limb is described by the location of the joint involved and the direction of the angle point
 A. Varus: Bowlegged
 B. Valgus: Knock-kneed

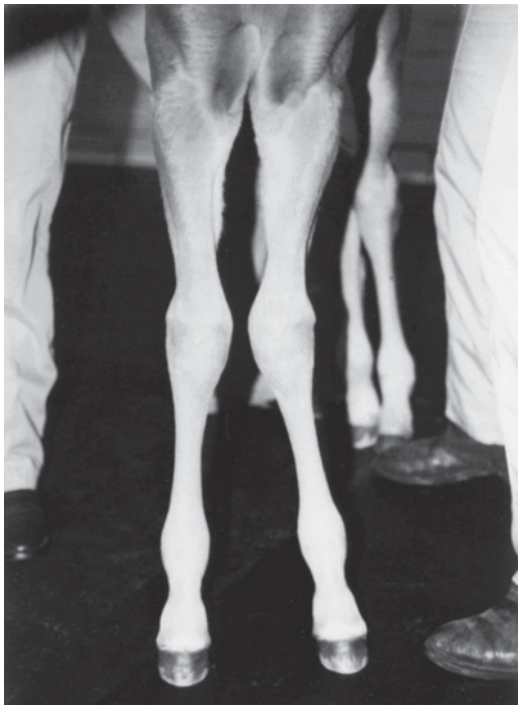


Figure 42-2 Carpus valgus deviation. (From Smith BP. *Large Animal Internal Medicine*, 3rd ed. St Louis, 2008, Mosby.)

VI. Cause
 A. Asymmetric growth of the long bones
 B. Abnormal weight-bearing on the limb such as with lameness
 C. Inflammation of the growth plate (physitis)
 D. Excessive body development in relation to bone or joint development
 E. Injury to the growth plate
VII. Diagnosis
 A. Clinical signs
 B. Radiographs: Determination of the angle point (where two lines intersect)
VIII. Prognosis
 A. Can be crippling if untreated
 B. Lameness and eventual osteoarthritis or degenerative joint disease
 C. Early intervention is imperative for a positive outcome
IX. Treatment
 A. Stall rest and diet modification (lower protein diet) for 4 to 8 weeks
 B. Limb casts or splints
 1. Limb casts or splints are required if the angular limb deformity (ALD) is because of weak ligaments and bones associated with the affected joint
 2. Cast or splint may be applied to the limb to help support the limb and maintain it in a straight position until the ligaments and bones mature enough to hold the weight of the foal
 C. Surgery: Severe forms of ALD require surgery
 1. Periosteal stripping or transection
 2. Lifting the covering of the bone (periosteum) just above the growth plate on the "short" side of the long bone
 3. Transphyseal bridging
 a. Transphyseal bridging involves placing a screw in the long bone above and below the growth plate on the "long" side of the bone and placing a piece of stainless steel wire between them
 b. Goal is to slow or stop the growth on that side of the bone at the growth plate so that the other side can catch up
X. Prognosis: Good outcome for future performance if the condition is not severe

Supplemental Reading

Read S, Bayly W, McEachern RB, and Sellon D. *Equine Internal Medicine,* 2nd ed., St Louis, 2003, Saunders.

43 CHAPTER

Preventive Medicine

Rebecca S. McConnico

VACCINATION

I. Active immunization
 A. Definition: Vaccination
 B. Goal
 1. Prolonged strong immunity
 2. Free of adverse side effects
 3. Ideal vaccine
 4. Stable
 5. Inexpensive
 6. Effective
 7. Adaptable to mass vaccination
 C. Vaccination practices are guided by:
 1. Tradition
 2. Likelihood of exposure to a particular infectious agent
 3. Limited research data
 4. Scientific studies
 D. Safety studies: Required by the Food and Drug Administration for market approval
 1. Efficacy studies are necessary but not required
 2. Controlled, blinded efficacy studies
 a. Expensive
 b. Time-consuming

II. Considerations for designing an effective vaccination program
 A. Cost and risk of disease vs. cost and risk of vaccination
 B. Zoonotic potential (e.g., rabies)
 C. Endemic diseases vs. rare or disease-outbreak situations; natural vaccine vs. man-made vaccine
 D. Vaccines available for horses in the United States
 1. Tetanus
 2. Equine herpes virus type 1 (EHV-1)
 3. Equine herpes virus type 4 (EHV-4)
 4. Eastern equine encephalomyelitis (EEE)
 5. Western equine encephalomyelitis (WEE)
 6. Venezuelan equine encephalomyelitis (VEE)
 7. West Nile virus encephalomyelitis (WNV)
 8. Influenza
 9. Strangles
 10. Rabies
 11. Potomac horse fever
 12. Rotavirus
 13. Botulism
 14. Anthrax
 E. Fatal diseases in horses with a safe and effective vaccine such as tetanus
 F. Often fatal neurologic disease
 1. Arboviral encephalitis (Eastern, Western, Venezuelan, West Nile) with high mortality (greater than 50% for EEE)
 2. Rabies (efficacy of vaccine for horses is unknown)
 G. Highly contagious diseases of horses with safe and effective vaccine availability
 1. Influenza
 2. Herpes types 1 and 4: Respiratory disease and abortion. Remember that the herpes vaccine does not protect against the neurologic form of herpes (herpes myelitis)
 3. Strangles vaccine (*Streptococcus equi*): Several adverse side effects have been associated with strangles vaccines
 H. Types of vaccines
 1. Attenuated: Flu, herpes, equine viral arteritis (EVA), all encephalitis (EEE, WEE, VEE, WNV, rabies), strangles, tetanus, equine protozoal myelitis
 2. Modified-live (e.g., intranasal; stimulate secretory immunoglobulin A)
 a. Herpes
 b. Influenza
 c. Strangles: Aerosol, intranasal
 3. DNA
 a. Humoral and cell-mediated immunity
 b. Recombinant: WNV

III. Vaccinating foals
 A. A relative lack of immune responsiveness in young foals to currently available vaccines. The frequent use of vaccines in the face of persistent maternal immunity may actually induce a state of tolerance, which can prevent a satisfactory response to vaccines past 1 year of age
 B. Tetanus
 1. Initial vaccination series: 2 to 6 months of age
 2. 6- to 8-week boosters are necessary if vaccination begins at 3 to 4 months of age
 3. Yearly boosters are necessary after the initial series
 4. Horses with a deep puncture wound or necrotic wound should be boostered (or initially vaccinated) regardless of vaccine status. It is not uncommon for these horses to receive tetanus antitoxin in addition to a toxoid

5. A horse that has never been vaccinated may be administered the tetanus antitoxin in a different site from the toxoid
6. Important points:
 a. Antitoxin may cause serum sickness in adults
 b. Needs to be boosted yearly
 c. Horses are the most susceptible species to tetanus the disease
7. Possible adverse side effect of using tetanus vaccine
 a. Theiler disease
 b. Acute hepatic necrosis
 c. Serum sickness
 d. Occur in the summer and fall
 e. Occurs within 4 to 10 weeks of vaccine
 f. Can be fatal

C. Equine influenza
1. A contentious issue in foal vaccination is the timing of the initial series of influenza vaccinations
2. Foals may be relatively immunologically unresponsive to many of the currently available vaccines
3. Nonprotective levels of antibodies may interfere with immune response
4. Equine "flu"
 a. Secondary upper respiratory tract and pulmonary bacterial infections are common because the virus compromises defense mechanisms
 b. Immunity resulting from natural disease lasts about 1 year
 c. Vaccinal immunity lasts about 3 to 4 months
5. Equine "flu" vaccine
 a. Needs to be type 2 strain with a date from the late 1980s or, ideally, the 1990s
 b. Current circulating strain of flu
 c. Vaccinate every 3 to 4 months in "traveling" horses
 d. Modified live virus (MLV) vaccine at least 2 to 4 weeks before potential exposure (and not less than 10 days)

D. Rhinopneumonitis = EHV-1 and EHV-4
1. EHV-1
 a. Abortion
 b. Respiratory disease
 c. Myelitis
2. EHV-4 Respiratory
3. Vaccine: EHV-1 and EHV-4
 a. Pregnant mares
 (1) For example, Pneumabort K, Ft. Dodge, Animal Health
 (2) Administer at 5, 7, and 9 months of gestation (some veterinarians administer at 3 months)
 (3) Only approved vaccine for herpes for pregnant mares
 b. Foals: MLV, begin at 3 months of age
 (1) Two additional vaccinations at 4- to 8-week intervals
 (2) Depending on exposure potential
 (3) Administer every 3 to 6 months
 c. Adult horses *not* in contact with broodmares probably do not need to be vaccinated
 d. Nonpregnant horses that are in contact with broodmares should be vaccinated for EHV-1 and EHV-4 every 3 to 6 months (at least twice a year)
 (1) Most effective herd management of herpes is to have all the adult horses on the same vaccination schedule
 (2) Does not protect against Herpes myelitis
 (3) Overvaccinating for herpes may contribute to the immune-mediated myelitis-vasculitis associated with the neurologic form of herpes

E. EEE and WEE
1. VEE not in the United States at this time
2. EEE and WEE
 a. Bivalent vaccine available
 b. Often combined with tetanus vaccine, influenza vaccine, or both
 c. Immunity is short-lived
 d. Vaccinate every 3 to 4 months in Florida, Alabama, Mississippi, Louisiana
 e. Foals
 (1) Florida: Begin at ~3 months of age and booster monthly until 6 months of age, then every 3 to 4 months after that through adulthood
 (2) Nonendemic areas: Begin at 3 months, then at least twice yearly during mosquito season
 f. Adults
 (1) Vaccinate at least twice a year (more often in the southeastern states)
 (2) Early spring and summer

F. WNV vaccine update
1. Vest DJ, Cohen ND, et al. Evaluation of administration of West Nile virus vaccine to pregnant broodmares. *J Am Vet Med Assoc* 225(12): 1894-7, 2004. (About 600 horses in Texas and Kentucky)
2. Peak equine cases occur in August-September-October
3. Equine central neurologic diseases (such as arbovirus encephalitides) may be reportable in individual states; nationwide monitoring
4. Florida has the most reported cases per year
5. Vaccine efficacy can be variable
 a. Dependent on climatic changes and vector populations
 b. Vaccinating every 6 months might not be enough

G. California and St. Louis encephalitis
1. May occur in horses
2. Not considered to be the source of serious disease in horses
3. Epidemiology is important for tracking human disease cases

H. Strangles vaccine
1. Intramuscular (IM)
 a. *Streptococcus equi equi*: Killed vaccine
 b. Initial series beginning at 2 to 6 months of age

c. Yearly vaccine for adults
d. Many reported adverse reactions to IM vaccine
(1) Local abscess
(2) Neck pain, myalgia, pyrexia
(3) Purpura hemorrhagica

2. Intranasal vaccine
a. *S. equi* vaccine
b. Live, attenuated (Pinnacle TM I.N. by Fort Dodge)
c. Intranasal
d. Adverse reactions
(1) Purpura hemorrhagica
(2) Bastard strangles
(3) Local abscessation at any injection site when given at the same time as Pinnacle

I. Rabies
1. Evidence that the vaccine is protective
2. Cannot rule out rabies for a horse that has rapidly progressing neurologic abnormalities even if the horse is vaccinated
3. Foals: Vaccinate at 3 months, then yearly
4. Approved rabies vaccine for horses: Should be considered a core vaccine for horses, especially in endemic rabies areas

J. Equine viral arteritis (EVA)
1. Transmitted via nasal secretions, venereally
2. Continues to become a growing problem
a. Thoroughbred
b. Arabian
c. Standardbred
3. Clinical signs
a. Fever, depression, anorexia, scrotal and preputial edema, limb edema, nasal and ocular discharge, and abortion
b. Affected horses usually recover
c. Carrier states are the problem
4. EVA
a. Vaccination is recommended on endemic farms to limit spread of EVA
b. Seronegative mares that are scheduled to be bred by carrier stallions should be vaccinated 3 weeks before breeding with an attenuated live vaccine
c. Do *not* vaccinate pregnant mares
d. Vaccinated horses are subject to export restrictions

K. Potomac horse fever (PHF)
1. PHF is the cause of fever, laminitis, and colitis in horses
2. *Neorickettia* (used to be *Ehrlichia*) *risticii*
3. Recommended in areas where PHF occurs
a. East Coast of the United States (especially Maryland, Potomac River area)
b. Occurs in 43 of 50 states in the United States
c. May occur in Canada, Europe, possibly worldwide
4. If the horse will be traveling to shows or meets
5. Frequency of vaccination may vary, depending on the horse's particular situation

BASIC EQUINE FEEDING GUIDELINES

I. Forage (grass hay or legume hay) is the basic food group for horses
A. Feed at least 50% of the total dry matter intake as forage (hay) with supplemental grain (concentrate) as necessary
B. Feed approximately 1.5% to 2% of the horse's body weight (1000-lb horse = 20 lb) per day
C. Concentrates should be at least twice daily and should not be more 0.5% body weight per feeding

II. Horses need only good forage and water as long as the mineral ration is correct Ca:P ratios around two parts Ca to one part P (2:1)

III. Horse should be fed on a regular schedule

IV. Horses should be allowed access to a clean fresh water source; daily water requirements are approximately ~25 L/day for a regular 450-kg body weight horse

V. Horses teeth should be examined once a year at minimum. Sharp points should be filed or floated (see Chapter 4, Dentistry)

INTERNAL PARASITES IN HORSES

I. Internal parasitism in horses:
A. Dull hair coat
B. Unthriftiness
C. Colic and death
D. Decrease immune response

II. Common equine parasites of concern
A. Large strongyles (bloodworms or redworms)
1. Known as bloodworms or redworms
2. Larvae penetrate the lining of the bowel and migrate along the blood vessels that supply the intestines
3. Infection with large strongyles can cause the following:
a. Unthriftiness
b. Weight loss
c. Poor growth in young horses
d. Anemia
e. Colic
4. Controlled with avermectin deworming products

B. Small strongyles
1. Do not penetrate the intestinal wall or migrate through the tissues
2. Burrow into the lining of the intestine and remain dormant, "encysted" enclosed in a cystlike structure), for several months before completing their life cycle
3. Encysted larvae are resistant to most dewormers
4. Infection with small strongyles can cause the following:
a. Colic
b. Diarrhea
c. Weight loss
d. Slowed growth
e. Poor coat condition
5. Treatment
a. Fenbendazole at twice the standard dosing for 5 consecutive days
b. Moxidectin

C. Roundworms (ascarids)
 1. Affects young horses (less than 10 months of age)
 2. Roundworms are several inches long and almost the width of a pencil
 a. Cause intestinal blockage (impaction)
 b. In large numbers, they can cause blockage (or impaction) of the intestine
 c. Roundworm larvae migrate through the internal organs until they reach the lungs, are coughed up, and swallowed
 3. Pregnant mares should be dewormed 30 days before foaling or at foaling to reduce the new foal's exposure to these parasites
 4. Only threadworms can be passed through the mammary gland in the horse
 5. Clinical signs
 a. Coughing
 b. Poor body condition
 c. Rough hair coat
 d. Pot-belly appearance
 e. Colic
 f. Heavily parasitized foals dewormed for the first time may become colicky with a massive kill of parasites (intestinal obstruction)

D. Tapeworms
 1. Clinical signs
 a. Colic
 b. Mild cramping or severe colic
 2. Life cycle specifics: Involves a tiny pasture mite, so horses with access to pasture are at greatest risk of developing tapeworm infection
 3. Effective treatment: Praziquantel

E. Lungworms
 1. Chronic coughing in horses, ponies, and mules
 2. Donkeys are the natural host of this parasite
 3. Do not show any obvious signs of infection

F. Pinworms
 1. Lay their eggs on the skin around the horse's anus
 2. Irritation causes the horse to rub its tail repeatedly

G. Bots
 1. Not a major health problem
 2. Can damage the lining of the stomach where they attach
 3. Effective drugs include ivermectin products, so rarely seen
 4. May cause small ulcerations in the mucosal lining of the mouth

H. Threadworms

III. Most troublesome equine internal parasites
 A. Large strongyles (bloodworms or redworms)
 B. Small strongyles
 C. Roundworms (ascarids)
 D. Tapeworms

IV. Life cycle
 A. Eggs
 B. Immature worms (larvae)
 C. Adult stages (mature worms)
 D. Eggs or larvae are swallowed while the horse is grazing → larvae mature into adults within the horse's digestive tract (stomach or intestines) → some species of larvae migrate out of the intestine into other tissues or organs before returning to the intestine and maturing into egg-laying adults

V. General signs of parasitism
 A. Dull
 B. Rough hair coat
 C. Lethargy (decreased energy) or depression
 D. Decreased stamina
 E. Unthriftiness or loss of condition
 F. Slowed growth in young horses
 G. Pot belly (especially in young horses)
 H. Colic
 I. Diarrhea

VI. Internal parasite management
 A. Fecal egg counts
 1. Allows monitoring of anthelmintic effectiveness
 2. Eggs per gram (epg) of 200 or less suggest light load, more than 500 suggests ineffective deworming and time to decrease interval between deworming
 B. Negative fecal sample does not mean the horse is free of internal parasites
 1. Encysted small strongyles
 2. Tapeworms

VII. Deworming (Table 43-1)
 A. Determination of deworming frequency is best done by treatment followed in 4 weeks with fecal egg counts

Table 43-1 Efficacy of Drugs in the Treatment of Equine Intestinal Parasites

Drug Class	Drug	Efficacy				
		Bots	Pins	Asc	LS	SS
Simple heterocyclic	Piperazine	-	+	+	min	R
Benzimidazoles	Fenbendazole, oxibendazole, mebendazole, etc.	-	+	+	+	+
Imidazothiazole	Levamisole	-	+	+	+	+
Avermectin	Ivermectin, moxidectin	+	+	+	+	+
Organophosphate	Tichlorfon, dichlorvos	+	+	+	+	+

+, Efficacy; *−*, not effective; *Asc,* ascarids; *Ls,* large strongyles; *Pins,* pinworms; *R,* resistance shown; *SS,* small strongyles.

B. Rotating products may be an effective method of deworming but may contribute to development of resistance in some species of parasites

VIII. Additional control strategies
A. Keep the number of horses per acre to a minimum to prevent overgrazing and reduce pasture contamination with parasite eggs and larvae
B. Pick up and dispose of manure regularly
C. Do not spread manure on fields to be grazed by horses
D. Periodic mowing of pastures
E. Consider rotating pastures
F. Keep foals and weanlings separate from yearlings and older horses to minimize the foals' exposure to roundworms and other parasites

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.

Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St Louis, 2009, Saunders.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

44 CHAPTER

Reproductive Disorders

Rebecca S. McConnico

MARE REPRODUCTIVE DISORDERS

I. Breeding history
 A. Sequential year-by-year account of the mare's entire career
 B. Mare background: Before breeding years
 C. Record of known problems
 1. Abortions
 2. Early embryonic death
 3. Twinning
 4. Neonatal deaths
 D. Complete list of live foals
 1. Live foals
 2. Sires
 3. Foaling dates
 E. Detailed records of foaling years
 1. Teasing date
 2. Breeding date
 3. Short cycles (if any)
 4. Prolonged diestral patterns (if any)
 5. Time of year bred
 6. Age of mare at breeding
 7. Young mares may have experienced abnormal cycles from training management practices
 F. Mulitparous mares
 1. May have reproductive conformational problems
 2. Stallion knowledge
 3. Management level for breeding

II. Physical examination
 A. Detect any problems in other systems that could affect fertility
 B. Determine behavioral issues, if any
 C. Determine mare's body condition
 1. Debilitation
 2. Obesity
 D. Feeding and management
 E. Dental care
 F. Parasite control

III. Reproductive tract examination: Restrain with twitch or lip chain
 A. External genitalia and perineum
 1. Best evaluated during estrus
 2. Conformational defects: Dorsal commissure of the vulva should be at least 4 cm dorsal to the pelvic floor
 B. Vaginal vestibule
 1. Windsucking: An intact vulvovaginal sphincter is present in a mare when the labia can be spread slightly without air entering the vestibule. Tone is important in preventing contamination of the cranial vagina and is absent in a chronic windsucker
 2. Estrus = vaginal vestibule is pink to red in color
 3. Anestrus = vestibule is pale with dry mucosa
 4. Inflamed vestibule = dark red or muddy color
 C. Rectal palpation of internal reproductive tract
 1. Be careful to guard against trauma to the rectal mucosa
 2. Do not counter against tenesmus or peristaltic waves
 D. Evaluate the ovaries
 1. Cup the body of the uterus with the hand, retract the uterus caudally, grasp the ovary (will need to reach laterally and dorsally). A large ovary may not be able to be grasped, but it can be stabilized for palpation
 2. Mesovarium attaches to the cranial half of the ovary; locate the ovulation fossa
 3. Follicles are fluid-filled structures that tend to project above the ovarian surface as they mature. Measure follicles in inches or centimeters. Collapse of the follicle is assumed to be ovulation; crater or pit formation. Corpus hemorrhagicum: Spongy but fills the crater left by the ovulation
 4. Mature corpus luteum (CL) = 5 days post ovulation
 E. Nonpregnant uterus palpation
 1. Size, tone, consistency, and general conformation and detailed examination of abnormalities
 2. Increased uterine tone indicates progesterone effects
 3. Tubularity = diestrus, whereas softening = estrus and anestrus
 4. Circulating estrogens cause tissue edema (uterine)
 5. Anestrus: The uterine wall is flaccid, thin, and quite indistinct
 6. Endometrial atrophy = anestrus
 7. Use the index finger to estimate the size of the uterine horn
 F. Cervical palpation
 1. Estrogen causes cervical relaxation and progesterone causes turgid/firm cervix
 2. Diestrus cervix is long, tubular, and readily palpable
 3. Anestrus: Cervix is soft and indistinct

G. Vaginoscopic examination and vaginal speculum examination
 1. Dilation of the vagina with air. Tail should be wrapped and perineal area carefully washed with a nonirritating soap. Moist cotton is used to wipe the inner edge of the labia. Asepsis is important to prevent uterine contamination
 2. Cervix is pale and dry in diestrus and soft and pink in estrus
 3. Abnormalities detectable: Mucosal hyperemia, suppurative exudates, persistent hymen, urine pooling, rectovaginal defects (Figure 44-1)

H. Endometrial ultrasound examination
 1. Ultrasound examination
 2. Visual examination of the cervix and vagina

I. Additional aids
 1. Cytologic examination: Presence of neutrophils in the uterine lumen is suggestive of inflammation
 2. Endometrial samples and biopsies
 3. Uterine culture
 4. Fiberoptic inspection
 5. Dorsal commissure of the vulva
 a. No more than 4 cm dorsal to the pelvic floor
 b. Pneumovagina
 c. Contamination
 d. Wind-sucking test: Apply uniform pressure with the hands on each side of the labia

IV. Ovarian diseases

A. Gonadal dysgenesis

B. Pathologic abnormalities of the ovaries
 1. Aberration of chromosomal segregation
 2. Chromosomal mosaics
 3. Most common abnormality: 63,X0 (missing sex chromosome)
 4. Other chromosomal abnormalities: 63,X0; 64,XX

C. Testicular feminization
 1. Male pseudohermaphroditism: 64,XY
 2. Inherited defect consistent with either autosomal dominant sex-linked mutation or sex-linked recessive mutation
 3. Major complaint is infertility
 4. Barren maiden mare with stallion-like behavior
 5. History of anestrus
 6. May be smaller in stature
 7. Teasing behavior may be agitated to passive avoidance
 8. Vulva and vagina may be hypoplastic but usually normal
 9. Flaccid cervix
 10. Underdeveloped uterus
 11. Very small ovaries
 12. Ultrasound of ovaries = lack of anechoic structures (no follicular activity)
 13. Does not respond to hormones
 14. Plasma estrogen levels are low
 15. Endometrial hypoplasia (endometrial biopsy)
 16. Plasma luteinizing hormone is high due to lack of negative feed back from estrogen
 17. Larger for their breed
 18. Appearance of stallions
 19. Small, firm inactive ovaries
 20. Diagnosis
 a. Clinical observation and examination
 b. Rectal palpation
 c. Determine sex chromatin appendages (drumsticks)
 21. Prognosis and treatment: Injectable or oral progesterone may eliminate unwanted behavior

D. Ovarian hypoplasia
 1. Phenotypically normal mare with infertility
 2. Occasional or very irregular heat cycles
 3. May allow a stallion to mount
 4. External genitalia are normal
 5. Uterus may be normal or undeveloped
 6. Ovaries are smooth, small, with no follicular activity

E. Ovarian hematoma (post-ovulation) (Figure 44-2)
 1. Post-ovulation: Postovulation follicular hemorrhage beyond normal limits in the postevacuation phase of ovulation leads to an ovarian hematoma

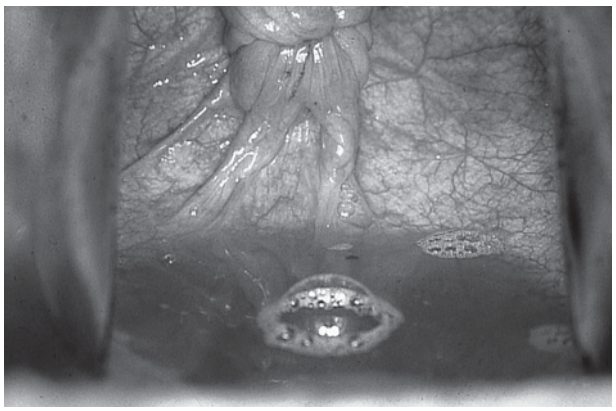


Figure 44-1 Urine and debris pooled in the anterior vaginal vault of a mare with urovagina. (From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)

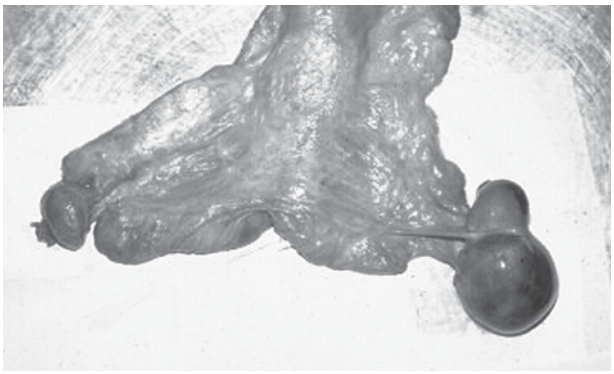


Figure 44-2 Ovarian hematoma of a mare. Mares with ovarian hematomas usually continue to have regular estrous cycles and do not have contralaterally atrophied ovaries. The enlarged ovary shrinks over time. Hormone assays reveal no abnormalities in hormone concentrations. (From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)

2. May be associated with an underlying blood coagulation disorder
3. May range in size of 5 to 12 cm but may become as large as 50 cm
4. Main differential for an enlarged ovary
5. Usually do not have abnormal behavior (compared with a mare with a testosterone-producing ovarian tumor)
6. Differences from other ovarian hematomas
 a. Identification of an ovulation fossa
 b. Contralateral ovary is normal in size and has follicular activity
 c. Normal estrus is displayed
 d. Luteinization and subsequent fertilization should occur normally
 e. Ultrasound architecture: Diffuse echogenic mottling
 f. May look similar via ultrasound to ovarian hematoma or normal corpus hemorrhagicum
7. Diagnosis
 a. Palpate a normal ovulation fossa
 b. Palpate a normal-sized and active contralateral ovary
 c. Observe normal estrus behavior associated with regular estrus cycle
 d. Rule out the possibility of a seasonal cause
8. Treatment
 a. Most resolve spontaneously after a variable time (usually two or three estrus cycles)
 b. Rarely the hematoma lasts and destroys ovarian germinal tissue

F. Ovarian abscess: Rare
1. Caused by three routes
 a. Hematogenous spread
 b. Ascending infection from the tubular reproductive tract
 c. Local extension from surrounding infected organs (perimetritis, etc.)
2. Clinical and diagnostic findings
 a. Diagnostic challenge
 b. Initially, enlarged ovary; elevated rectal temperature, increased white blood cell count (WBC)
 c. Chronic: Small and fibrotic; normal temperature and WBC count
 d. Transrectal ultrasound
3. Treatment
 a. Surgical removal
 b. Broad-spectrum antibiotics

G. Ovarian cysts
1. Anovulation: Anovulatory follicles are common during transitional periods
2. Rare during the ovulatory season
3. Normal anovulation and follicular cysts
4. Pituitary and circulating levels of luteinizing hormone not produced in enough quantity for an ovulatory surge

H. Ovarian neoplasm
1. Sex chord stromal origin
 a. Granulosa thecal cell tumors
 (1) Benign
 (2) Most common ovarian tumor
 (3) Behavior: Anestrus, irregular estrus, nymphomania, stallion-like behavior
 (4) Consistency: Firm and smooth or loculated, may be fluid filled, multiple follicular-like
 (5) Opposite ovary: Generally small and hard with no follicular activity
 (6) Endocrine: Serum testosterone is generally increased (stud-like behavior if greater than 100 pg/mL); estrogen variable; progesterone less than 100 pg/mL
 b. Arrhenoblastoma
 (1) Benign
 (2) Extremely rare
 (3) Stallion-like
 (4) Smooth and firm mass on ovary
 (5) Opposite ovary is generally hard with no follicular activity
 (6) Serum testosterone is elevated
 (7) Estrogen and progesterone are low
2. Epithelial (capsule): Adenocarcinoma (cyst)
 a. Malignant
 b. Extremely rare
 c. Normal behavior
 d. Unilobular or multilobular: Cyst adenomas and carcinomas have multiple cysts
 e. Opposite ovary has normal size and activity
 f. Generally nonsteroidal activity
3. Germ cell origin
 a. Teratoma
 (1) Benign
 (2) Second most common ovarian tumor
 (3) Normal behavior
 (4) Consistency of tumor: Firm or multiple follicular-like with bone or cartilage palpable
 (5) Irregular surface (points and edges)
 (6) Usually nonsteroidal
 b. Dysgerminoma
 (1) Malignant
 (2) Extremely rare
 (3) Normal behavior
 (4) Smooth surface
 (5) Soft or solid, lobulated, and multicycle

V. Uterine fluid
A. A cause for reduced fertility
B. Diagnosis
1. History of breeding-associated fluid retention
2. Ultrasound diagnosis of fluid retention is most useful
3. Signs suggestive of endometritis
 a. Glandular alterations
 b. Failure of lymphatic drainage
 c. Delay in physical clearance
 d. Decreased reabsorption of lymphatic vessels
 e. If greater than 1 cm identified during estrus, it should be drained

C. Treatment
1. Uterine lavage: 2 to 3 L of warmed buffered physiologic saline or lactated Ringer's solution using a large-bore (30 French) catheter
 a. It is safe to perform uterine lavage 4 hours

after breeding and up to 2 days from ovulation, provided isotonic fluids are used
b. Transrectal massage of the fluid is unnecessary. Use of intravenous (IV) oxytocin (20 international units single) will help with uterine clearance
2. Use of intrauterine antibiotics or plasma is controversial yet remains under investigation
3. Summary of treatment for intrauterine fluid accumulation resulting from mating-induced endometritis:
a. Clears within 1-2 days
b. Problems more serious in older mares
c. Breeding should occur at the optimum time
d. Ultrasound examination is useful

VI. Uterine infections
A. Caused by a mixture of the following:
1. Semen
2. Bacteria
a. *Streptococcus zooepidemicus* (β-hemolytic)
b. *Escherichia coli*
c. *Staphylococcus* spp.
d. *Klebsiella pneumoniae*
e. *Pseudomonas aeruginosa*
f. *Tayloriella equigenitalis* (causative agent of contagious equine metritis [CEM])
g. *Bacteroides fragilis*
3. Considered contaminants
a. α-Hemolytic *Streptococcus*
b. Staphylococci
c. Various enterics
4. Extender
5. Debris
6. Physical barriers to uterine infections include the vulva, vaginovestibular sphincter, and cervix
a. Physical barriers prevent feces, air, and environmental bacteria from entering the reproductive tract
b. Problems with physical barriers include forward-tilted pelvis, poor perineal conformation, tendency to suck air into the vagina; urine pooling causes sterile inflammation, which can decrease fertility. Caslick's will help compensate for an insufficient sphincter

B. Diagnosis
1. Ultrasound examination
a. Fluid greater than 0.5 to 1 cm is an abnormal finding
b. Determination of ovulation time is vital
2. Vaginal speculum examination
3. Uterine culture and cytological examination: Negative culture to the following is required before breeding
a. *Klebsiella pneumoniae*
b. *Pseudomonas aeruginosa*
c. *Tayloriella equigenitalis* (CEM)
4. Endometrial cytology and culture (Figure 44-3)
a. Normal uterine cytology: No intraluminal neutrophils; normal to have epithelial cells
b. Collection: Swabbing, aspiration, or curettage
c. Uterine swab: Use same as that for uterine culture, briskly rotate, and allow fluid or cell debris to fill the cap. Place collected sample on the slide and submit the swab sample for culture
d. Best time to culture is the first day of standing estrus
e. Stain: Diff Quick, Harleco for cytology; must see normal epithelial cells
5. Endometrial biopsy (adjunct to complete examination)
a. Indications
(1) Barren mares with clinically evident abnormality of the reproductive tract that fail to conceive after repeated breedings
(2) Nonpregnant mares presented for prepurchase for fertility examination
b. Use 70-mm alligator punch
c. Histology category
(1) Category I: Endometrium compatible with conception and capable of supporting a foal to term. No endometrial atrophy or hypoplasia is seen. Mares have a 70% or greater chance for producing a live foal
(2) Category II: Mares with endometrial changes that reduce the chance of conception and pregnancy maintenance but that are reversible or only moderately severe: Slight to moderate diffuse cellular infiltrations of superficial layers; scattered but frequent inflammatory or fibrotic foci throughout the entire lamina propria; scattered but frequent periglandular fibrosis of individual gland branches of any degree of severity. Pregnancy rates range from 30% to 70% (category IIa, more inflammation; category IIB, fibrosis)
(3) Category III: Endometrial changes that reduce chances of conception and pregnancy maintenance; widespread

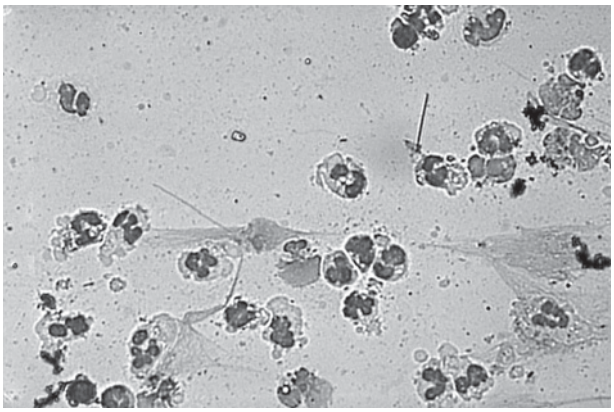


Figure 44-3 Cytologic preparation (hematoxylin-eosin stain) of acute endometritis associated with *Streptococcus* infection. Cytologic preparations from mares with acute or subacute endometritis yield numerous neutrophils that are often degenerate and may contain phagocytosed bacteria along with many singular, degenerate epithelial cells. (From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)

periglandular fibrosis of any degree with five or more nests in an average low-powered field; less than 10% chance of conceiving

C. Treatment of uterine infections includes penicillin, ampicillin, amoxicillin, ticarcillin, neomycin, genatmicin, kanamycin, polymyxin, and ceftiofur

VII. Induction of ovulation
A. Lighting
1. Mares are commonly kept under lights during winter months to initiate cycling early in the year
2. Cycling commences 8 to 10 weeks after the lighting program has begun. Target cycling for February; lighting must be initiated in November
3. Ideal photoperiod = 16 hours of light
4. Lights should be turned on in the evening
5. Extending photo period by turning lights on before dawn is less effective
6. Requires 2 foot-candles of light = use 200-W bulb over a stall in which the mare is no more than 8 feet from the light source

B. Gonadotropin-releasing hormone (GnRH) and its agonists
1. Induction by GnRH administration
2. Single injections do not work
3. Requires GnRH to be delivered in a pulsatile fashion or by sustained release
4. Pulsatile release of GnRH by osmotic pumps will induce ovulation. The GnRH agonist Ovuplant is currently available

C. Induction of ovulation with human chorionic gonadotropin (hCG)
1. hCG is commonly used in cycling mares to induce ovulation
2. Ovulation occurs 24 to 48 hours following administration of 1500 to 3300 international units administered IV or intramuscularly (IM) if a growing, dominant follicle larger than 35 mm is present. 2500 international units is a common dose. Given early in estrus, ovulation usually occurs 36 to 42 hours after injection
3. hCG is not effective in large follicles that are regressing
4. hCG used post insemination to hasten ovulation and to minimize number of inseminations

D. Short cycling with prostaglandins
1. Shortening the length of diestrus is a common method of managing brood mares
2. Allows spreading or grouping of mares for breeding
3. Shortens the waiting period following missed ovulations
4. Exogenous prostaglandin administered to the diestrous mare lyses the CL, causing return to estrus
5. Common method: IM injection of 5 mg to 10 mg dinoprost tromethamine (Lutalyse).
a. CL resists prostaglandin in the first 4 to 5 days post ovulation but becomes responsive after this time
b. Best response is achieved when administered between day 6 and 9 post ovulation
c. Predicting the response to prostaglandin depends on degree of palpation of mares before prostaglandin injection, and diligent teasing is necessary to cope with variable responses. Normal side effects of Lutalyse injection include transitory sweating and mild colic, which usually completely resolve within an hour of injection
6. Medical uses of prostaglandins
a. Persistent corpus luteum
b. Pyometra

VIII. Suppression of estrus
A. Estrous behavior may be a problem in show mares
B. Altrenogest (0.044 mg/kg once daily, administered orally [PO]) is effective in suppressing estrous behavior in mares
C. Progesterone in oil (150 mg twice daily IM) may be a cheaper alternative
D. If the horse is in estrus at the start of treatment, estrus behavior is usually suppressed in 2 to 3 days
E. Anabolic steroids, such as stanazolol (Winstrol) or boldenone undecyclate (Equipoise), are administered as performance enhancers. Although these steroids effectively suppress estrus, long-term administration may lead to objectionable stallion-like behavior and prolonged suppression of ovarian function. Anabolic steroids are not recommended for horses intended for reproduction

IX. Synchronization of estrus
A. Synchronization of estrus is a requirement for donors and recipients in embryo transfer programs
B. May be helpful in scheduling breedings
C. Progestogens may be used to synchronize estrus (altrenogest 0.044 mg/kg once daily PO or 150 mg progesterone in oil for 8 to 12 days)
D. Following withdrawal, prostaglandin is administered, and estrus occurs in about 3 to 6 days and ovulation in 8 to 15 days. The variable time to ovulation arises from progestogens' inability to inhibit follicular development (remember that progesterone does not inhibit follicle-stimulating hormone [FSH] secretion in the mare). The addition of estradiol 17-β to the protocol inhibits follicular development and improves synchrony. The most effective protocol for synchronizing estrus in mares consist of daily progestin (altrenogest 0.044 mg/kg once daily PO or 150 mg progesterone in oil once daily IM) with daily estrogen (10 mg estradiol 17-β) for 10 days. Prostaglandin is given on the last day, and mares will ovulate within 10 to 12 days of the last treatment

X. Induction of estrus behavior
A. Collection of semen from a stallion frequently requires an estrous mare. Ovariectomized mares given 1 to 4 mg IM of estradiol cyprionate (ECP) will show heat in 6 to 20 hours
B. Exogenous estradiol will not induce estrus in ovarian intact mares if a CL is present
C. ECP (single injection of 1 mg ECP) has been used to induce estrous behavior in silent heat

mares when breeding must occur by live cover
D. Exogenous estrogens should be used with caution due to potential side effects

XI. Maintenance of pregnancy
A. Prevention of prostaglandin release
1. Unwanted, luteolytic release of prostaglandin may terminate early pregnancy
2. Possible stimuli to cause prostaglandin release include
a. Endotoxemia (e.g., from colic)
b. Cervical manipulation (e.g., transcervical placement of an embryo)
c. Uterine manipulation (manual twin reduction)
3. Flunixin meglumine may be helpful in preventing prostaglandin release if given in advance
4. In potentially endotoxic situations, flunixin meglumine should be included
B. Progestogens
1. Progestogen supplementation to mares suffering an endotoxic insult in the first 90 days of gestation is a wise and necessary precaution
2. Because luteolysis may have occurred, supplementation needs to be extended at least through 90 days, if not to 120 days
3. Altrenogest is a convenient but expensive source of oral progestogens
4. Mares without any history of endotoxemia may be presented for progestogen supplementation for pregnancy maintenance (controversial issue)

XII. Pregnancy termination
A. Day 0 to 5: Impossible because CL is refractory to prostaglandins
B. Day 5 to 35: Single luteolytic dose of prostaglandin is effective. Mare should cycle back normally and can be rebred
C. Day 35 to 160
1. After formation of the endometrial cups, response to a single dose of prostaglandins is variable, but repeated doses (once or twice daily for 3 to 5 days) should be effective before day 70
2. Sequelae: Cyclicity is variable due to the presence of the endometrial cups; estrous cycles may be irregular; efficacy of prostaglandin will continue to decrease as the placenta becomes the primary source of progestogens
D. Day 160 to 310: Neither prostaglandins nor corticosteroids will induce abortion during this period. Oxytocin does not become effective until after day 310

XIII. Parturition induction
A. Fetal readiness: Calcium greater than 40 mg/dL; sodium:potassium ratio inverted (potassium is greater than sodium)
B. Prostaglandins. At about 320 to 330 days, prostaglandins become effective in terminating pregnancy. However, they vary greatly with respect to fetal readiness for birth:
1. Prostaglandin F2-α. Single injection can terminate pregnancy in approximately 3.5 hours, but foal will not survive unless other parameters of readiness for birth are met. Response is variable, and complications frequently reported
2. Fluprostenol: Effective if the foal is ready for birth. Ineffective in terminating pregnancy if foal is not ready. Foaling takes place within 1 to 6 hours, which is a disadvantage compared with oxytocin
3. Oxytocin
a. The drug of choice for induction of parturition. Will terminate pregnancy after 310 days, regardless of fetal maturity; so fetal readiness for birth must be determined
b. Low doses (e.g., 2.5 to 10 units) give smoother delivery than larger doses (greater than 40 units). Can be repeated every 20 minutes. Foaling usually begins in 15 to 30 minutes and is complete within 1 hour
4. Corticosteroids: Although effective in other species, they are essentially ineffective in inducing parturition or terminating pregnancy in the mare

STALLION REPRODUCTIVE DISORDERS

I. Definitions and anatomy
A. Puberty: The age at which a male can successfully impregnate a female
B. Testicles
1. Must be able to thermoregulate. Requires the following:
a. Countercurrent blood flow located at the level of the pampiniform plexus
b. Ability to contract and relax the cremaster muscles
c. Scrotal sweat glands
2. Sertoli cells: Supportive cells that contain most testicular receptors for FSH. Importance in spermatogenesis:
a. Prevent immune system in animal recognizing them as non-self
b. Endocrine and exocrine function
c. Specific germ cell stages
d. Movement and shaping of germ cells
3. Leydig cells
a. Interstitial cells
b. Contain most of the testicular receptors for LH and the main site of steroid production (testosterone and estrone sulfate)
C. Epididymis
1. Single convoluted duct of approximately 70 to 80 m long
2. Three segments
a. Head or caput
b. Body or corpus
c. Tail or cauda
3. Spermatozoa must go through epididymal maturation process to be fully competent for fertilization
D. Accessory sex glands (Figure 44-4)
1. Paired seminal vesicles
2. Bulbourethral glands
3. Bi-lobed prostate

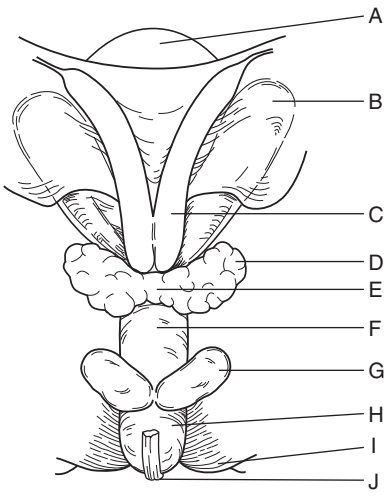


Figure 44-4 Accessory genital glands of the stallion (dorsal view): *A,* bladder; *B,* right vesicular gland; *C,* right ampulla; *D,* right lobe of the prostate gland; *E,* isthmus of the prostate gland; *F,* urethralis muscle; *G,* right bulbourethral gland; *H,* bulbospongiosus muscle; *I,* right ischiocavernosus muscle; and *J,* retractor penis muscle. (Modified from Varner DD, Schumacher J, Blanchard TL et al. *Diseases and Management of Breeding Stallions.* St Louis, 1991, Mosby; From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)

E. Penis
 1. Musculocavernous type
 2. Prepuce covers the retracted glans penis
F. Reproductive behavior and breeding behavior: Dependent on breeding experience, management, and season; influenced by auditory, visual, and olfactory stimuli

II. Diseases of the male reproductive tract
A. Hermaphroditism: Having both testicular and ovarian tissue
B. Pseudohermaphroditism: Have tissues of either testis or ovaries but also have various combinations of male and female internal reproductive organs; most common is the male pseudohermaphrodites
C. Testicular feminization
 1. Androgen insensitivity: Normal XY karyotype and male behavior but female genotype
 2. Reproductive tract is underdeveloped, and only external female genitalia are present
 3. Diagnosis: Visual inspection of the external genitalia, rectal palpation, and ultrasound examination, but definitive examination by cytogenic evaluation is required
D. Scrotal defects
 1. Edema is usually due to trauma
 2. Other causes of scrotal edema: Systemic infectious processes, scrotal hernias, spermatic cord torsion, hemorrhagic processes
 a. Infectious causes, viral: equine infectious anemia (EIA), equine viral arteritis (EVA), or diseases causing hypoproteinemia
 b. Neoplasias: Melanomas, sarcoids
 c. Parasitic
 (1) *Trypanosoma equiperdum* (dourine – reportable)
 (2) *Oncocerca cervicalis* (microfilaria) and summer sores (*Habronema* spp.)
 3. Treatment: Remove primary cause, control inflammation, supportive therapy. Antiinflammatory drugs, diuretics, cold hydrotherapy. Administer tetanus toxoid booster
E. Testicular defects
 1. Ectopic testis (cryptorchidism): A gonad that fails to reach the scrotum and deviates from the normal path of descent
 a. One or both testicles are in an ectopic location, although the gonads remain in the normal path of the testicular descent. Testis epididymis is located in or around the internal inguinal ring just cranial to the pelvic brim slightly off midline
 b. Hormone levels (testosterone or estrone sulfate) (take samples after stimulation with 5000 to 12,000 international units of hCG 30 and 60 minutes post stimulation and 24 hours after)
 2. Gonadal hypoplasia: Small testis
 3. Gonadal atrophy
 4. Testicular hypertrophy
 5. Testicular neoplasia
F. Orchitis
 1. Bacterial
 a. *Brucella abortus*
 b. *Actinobacillus equuli*
 c. *Pseudomonas pseudonmallei*
 d. *Streptococcus zooepidemicus*
 e. *Streptococcus equisimilis*
 f. *Salmonella* spp.
 g. *Escherichia coli*
 h. *Staphylococcus* spp.
 2. Viral: EIA or EVA
 3. Parasitic: *Strongylus edentatus*
 4. Traumatic
G. Seminal defects
 1. Urospermia
 2. Hemospermia
 3. Bacterispermia
H. Penis, prepuce, and urethra dysfunction
 1. Penile paralysis
 2. Priapism
 3. Paraphimosis
 4. Occurs in malnourished or exhausted horses
 5. Spinal lesions
 6. Loss of retractor penis muscle
 7. Can result in ulceration, bacterial contamination, necrosis
 8. Requires mechanical support of the penis
 a. Antiinflammatories
 b. Diuretics
 c. Topical emollients
I. Penile tumors
 1. Squamous cell carcinoma is most common. Treatment is cryosurgery, phalectomy, laser surgery, reefing
 2. Penile warts
 3. Sarcoids
 4. Squamous papillomas

5. Melanomas
6. Fibromas

J. Venereal diseases
1. *Klebsiella pneumoniae* (types 1, 2, and 5) or *Pseudmonas aeruginosa* (types 2, 3, and 5); can become pathogenic; however, maybe part of the normal microflora
2. EVA: Asympotomatic stallions can transmit it to susceptible mares and cause abortion outbreaks. Disease can cause mild flu-like symptoms or severe depression and febrile periods and edema of ventral abdomen, prepuce, and scrotal area
3. Coital exanthema: Caused by equine herpes virus 3; pustules and ulcers
4. Contagious equine metritis: Caused by *Taylorella equigenitalis*; reportable disease
5. Dourine: Caused by *Trypanasoma equiperdum*; acute edema of the genital area; silver-dollar plaques

BREEDING MANAGEMENT

I. Breeding types
A. Pasture breeding
1. Stallion is turned out with a group of mares for the breeding season
2. Mares may be examined for pregnancy to monitor progress
3. Venereal diseases can be transmitted under these conditions from mare to mare via the stallion

B. Hand breeding
1. Stallion brought to mare and breeding takes in the breeding shed by live cover. Thoroughbreds are required to be bred this way
2. Semen is viable for up to 5 days in the mare but is usually viable for 48 to 72 hours

C. On-site artificial insemination (AI)
1. Stallion is collected into an artificial vagina and the semen is collected, analyzed, extended, and perhaps divided between several mares
2. Mares are bred immediately after semen collection
3. Fresh semen viability in the mare is at least 48 to 72 hours with a healthy stallion

D. Shipped cooled semen
1. Stallion's semen is collected
2. Semen is chilled and shipped by courier or overnight express to the mare
3. Viability of shipped cooled semen in the mare is about 24 hours
4. Semen is frequently shipped in the blue Equitainer

E. Frozen semen
1. The stallion's semen is collected
2. Sperm is extended and frozen in liquid nitrogen
3. Frozen semen may be stored indefinitely, perhaps for several years or even longer than the stallion's lifetime
4. Can be shipped internationally
5. Longevity of frozen semen in the mare is very low, usually about 8 hours at the most. So mares must be bred very close to ovulation. Frozen-semen breeding is very labor intensive, and conception rates are low. However, the value of the foal frequently justifies the effort

II. AI
A. Semen dose: 500 million normal motile cells
B. Semen extender
1. Kenney extenders/skim milk
2. Antibiotics

C. Protect semen from the following:
1. Light
2. Heat and cold
3. Air
4. Blood and urine

D. Intrauterine insemination
1. 35-mm follicle or greater
2. Give hCG
3. Breed before ovulation
4. Deposit semen in uterus via cervix
5. Avoid syringes with siliconized rubber

E. Multiple horses
1. An ejaculate of 10 billion normal cells could breed 20 mares (10/0.5 = 20)
2. Check breed restrictions

F. Chilled semen
1. Overnight or same-day delivery
2. Problems
a. Stallion collection schedule
b. Palpating the mare at Monday, Wednesday, and Friday (MWF) or every day
c. Judging the timing
d. Shipping delays
e. Cost per breeding
3. Methods
a. Equitainer
b. Styrofoam boxes
4. Breed Restrictions: Not all breeds or stakes programs allow this

G. Frozen semen
1. General
a. Egg yolk and other extenders
b. Prevent ice crystal damage to membranes
c. Store semen in straws in liquid nitrogen
d. Lasts "forever"
e. Can breed to a dead stallion
2. Problems
a. Variable post thaw motility between stallions
b. Not all stallion semen freezes well
c. Usually survives 8 hours or less in mare
d. Need to breed within 8 hours of ovulation
3. Breeding procedure
a. Read thawing instructions that come with straw
b. Protocol (there are alternatives)
c. Ultrasound every day until follicle is greater than 35 mm
d. Give 2500 international units of hCG
e. Ultrasound or palpate every 8 hours for ovulation
f. If the mare ovulates, breed her

g. If no ovulation has occurred by 32 hours, breed at 36 hours
h. Continue to check for ovulation
i. Very labor intensive
j. Much more difficult than breeding cows with frozen semen

III. Embryo transfer (ET)
A. Advantages
1. More than one foal per year
2. Mare can keep showing
3. Risk of birthing borne by recipient
B. Outline of procedure
1. Synchronize donor and recipients
2. Lots of recipients helpful
3. Flush at 7 days post ovulation
4. Ideally, want an unhatched blastocyst (more hardy)
5. Implant into recipient: Surgically or transcervically
C. Success rates
1. Variable
2. 50% of flushes to get an embryo
3. 50% of embryos implant successfully
4. Therefore one pregnancy for every four flushes
D. Commercial ET
1. Large farms with many recipients
2. Texas, Colorado
3. Send flushed embryo by courier in an Equitainer
4. Cost is about $4000+ per pregnancy

IV. Management of the mare
A. General
1. Make sure mare is cycling before you breed her
2. Accurate and thorough records are essential
a. Teasing
b. Palpation and ultrasound records
c. Left ovary-right ovary
d. Follicular development and size
e. Breeding, name of stallion, semen parameters, hCG given?
f. Day of ovulation
g. If fluid in uterus post breeding
h. Pregnancy check 14 days post ovulation
i. Pregnancy check at 21, 28, 35, 60, 90, and 120 days
j. Foaling date
B. Tease
1. Tease mares every day or MWF
2. Start palpating mares when they come in heat
3. Identify mares that show heat for only one day
4. Pregnant mares should not return to heat
C. Injections
1. Prostaglandin F: Given in diestrus to bring mare into heat
2. hCG: Given in estrus (35-mm follicle) to make mare ovulate
3. Oxytocin: Given post breeding to make mares dump out excess uterine fluid

V. Pregnancy
A. Early pregnancy check
1. Ultrasound between 13 and 15 days after ovulation to detect twins
2. Twin reduction can be successful if done early
3. After day 16 the embryo adheres and cannot be moved, making successful reduction difficult
B. Fetal viability
1. By ultrasound the foal's health can be assessed
2. Fetal heart rate can be seen by ultrasound by day 23 and even better by day 28
3. Embryonic death occurs until day 35
4. Ideally, mares should be rechecked. Recheck on day 60 and day 120
C. Nutritional needs
1. Mares' nutritional needs begin to increase during the third trimester
2. Mares' nutritional needs are the highest during lactation
3. Mares should be fed according to their weight gain and needs

VI. Foaling
A. Signs of foaling
1. Enlarging abdomen over the last trimester
2. Mammary development over last 2 or 3 weeks
3. Slackening of pelvic ligaments and vulva
4. Milk in the udder
5. Waxing of teats (white colostrum at end of teats) last 48 hours
6. Milk electrolytes changes - increasing calcium
B. Normal foaling process
1. Stage I
a. Mare may be restless and colicky for about 2 hours
b. Uterus is beginning to contract and move foal into birth canal
c. Signs vary from mare to mare
d. Tail may point straight out
e. May urinate frequently
f. If possible, wrap the mare's tail
2. Stage II
a. Allantoic fluid rupture
b. Mare may stand or lie down to strain
c. Amnion, a white membrane, appears at the vulval lips, covering one front leg with the other a few inches behind (Figure 44-5)
d. The muzzle follows shortly after
e. Mare strains forcibly
f. Fetus is expelled in about 5 minutes, wrapped in the amnion
g. If it covers the nose the amnion should be broken so the foal can breathe
3. Stage III
a. The placenta should be passed within 3 hours
b. If it has not been passed in 6 hours it is a medical emergency
c. Owner should be educated to call the veterinarian for assistance
d. Do not pull the placenta from the mare
e. Placenta should be saved for examination
C. Abnormal foaling red bag delivery; chorioallantoic; premature placental separation (Figure 44-6)

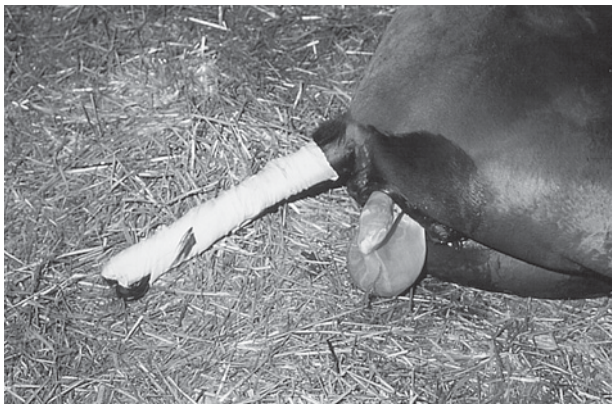


Figure 44-5 The white, glistening structure protruding from the vulva is the amnion, which contains the amnionic fluid. One foot is detectable within the amniotic cavity. (From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)



Figure 44-6 Chorionic surface of an unruptured placenta presented beyond the vulva as a result of premature placental separation. (From Brinsko S, et al. *Manual of Equine Reproduction*, 3rd ed. St Louis, 2011, Mosby.)

D. Induced foaling
 1. Using milk electrolyte, veterinarians may choose to induce foaling in high-risk mares
 2. Milk electrolytes indicate fetal readiness for birth

VII. Care of the new foal
 A. 1 minute after birth
 1. Heart rate (HR) = 60 to 80 beats/min
 2. RR = 60 beats/min
 3. Flexing of extremities
 4. Sternal position
 5. Nasal stimulation
 a. Cough
 b. Sneeze
 B. Time to suck = 2 to 20 min (usually)
 1. If not sucking after 2 hours, call the vet!
 2. Sternal = 1 to 2 minutes
 3. Time to stand and nurse: Not longer than 2 hours (up to 3 hours)
 4. Temp = 99 to 101.5° F
 5. HR up to 100 to 120 beats/min

VIII. Postfoaling procedures
 A. Allow cord to break on its own (unless foaling in mud, dirt, or manure)
 B. Ligation of cord: 2.5 in. from body wall
 C. Apply 2% chlorhexidine solution to umbilical cord twice daily for 48 hours
 D. Examine placenta for tears (retention of placenta)
 E. Physical examination of the foal
 F. Administer tetanus anti-toxin if mare did not have a booster in last trimester
 G. Immunoglobulin G test (can do as early as 4 to 6 hours of age)
 H. Warm, soapy water enema. Not recommended to use commercial Fleet enemas on foals
 I. Check the specific gravity of the mare's colostrum = 1.060 or greater. This indicates sufficient antibodies in the milk. A veterinary examination should be performed on the foal to detect any congenital abnormalities

Supplemental Reading

Blanchard TL, et al. *Manual of Equine Reproduction,* 2nd ed. St Louis, 2002, Mosby.

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.

Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St Louis, 2009, Saunders.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2009, Mosby.

45 CHAPTER

Respiratory Disorders

Rebecca S. McConnico

RESPIRATORY EXAMINATION

I. History
 A. Exact complaint
 1. Description of problem
 2. Frequency
 3. Duration
 B. Type of housing and bedding
 C. Are other animals sick?
 D. Age of horse
 1. Infections more common in younger horses
 2. Chronic airway disease more common in older horses
 E. Additional questions to ask
 1. Associated with work?
 2. Weight loss or gain?
 3. Duration of ownership?
 4. Recent change of environment?
 5. Acute or gradual onset?
 6. Previous surgery?
 7. Vaccination status?
 F. Observation of environment

II. Physical examination
 A. Attitude
 1. Depressed: Bacterial or viral infection (e.g., bacterial pneumonia)
 2. Bright, alert, responsive: Allergy (e.g., summer pasture associated recurrent airway disease [RAD], such as indoor RAD)
 B. Weight loss: Chronic disease (e,g., thoracic abscess)
 C. Observation from a distance: Respiratory pattern
 D. Sinus percussion
 1. Use fingers to percuss
 2. Percuss both sides
 3. Open mouth and move tongue to side for increased resonance, sounds
 4. Pain on percussion
 E. Ancillary tests
 1. Endoscopy
 2. Ultrasound
 3. Transtracheal wash (TTW)
 4. Bronchoalveolar lavage (BAL)
 5. Radiography
 6. Pleuroscopy
 F. Nasal exudate
 1. Location
 a. Nostril?
 b. Waterer or feeder?
 2. Character of exudate
 a. Color
 (1) Whitish yellow = bacterial (usually). Most common bacterial isolate? *Streptococcus equi zooepidemicus*
 (2) Beige-tinged or white: Bronchitis (chronic obstructive pulmonary disease [COPD] or other)
 (3) Blood-tinged
 b. Viscosity: Serous discharge can be normal or due to viral infection
 3. Intermittent discharge
 4. Only when the head is lowered
 5. Unilateral or bilateral: Unilateral+ = inus or guttural pouch
 6. Odor: Anaerobic infection?
 G. Lymph node palpation
 1. Submandibulars
 2. Thyroid gland
 3. Parotid gland
 4. Retropharyngeal
 H. Symmetry of the head
 1. Nostril flaring?
 2. Nostril width, symmetry
 3. Facial swelling
 4. Jugular vein thrombosis
 5. Sinusitis
 a. Bone cyst
 b. Neoplasia
 c. Abscess (osteomyelitis)
 6. Laryngeal excursion
 7. Palpate submandibular swelling (painful?)
 I. Breathing patterns: Character and rate
 1. Two phases
 a. Inspiratory: Active
 b. Expiratory: Passive
 2. Abnormal patterns
 a. Forced expiration: Most common
 b. Obstructive lung disease
 c. Rapid shallow
 d. Suggests restriction
 e. "Catch" (hesitation) to inspiration
 3. Breathing patterns with no pain
 a. Restrictive pneumonia
 b. Atelectic lung
 c. Pneumothorax
 d. Botulism
 4. Pain and restrictive pattern
 a. "Catch" (hesitation) to inspiration

b. Abducted forelimbs
c. Does not like walking down an incline
d. Does not like to lie down
e. Difficulty raising and lowering head
f. Grunt when touched over the thorax
g. Soft cough: Protects the chest
h. Fractured ribs = ± pleural pain

5. Obstructive pattern
a. Two-phase expiratory effort
b. Increased abdominal expiration (push at the end of expiration)
c. COPD, RAD
d. Increased pumping effort
e. Horses may have increased flatulence
f. *Rhodococcus equi* foal pneumonia

6. Upper airway obstruction pattern
a. Breathing is anxious
b. Horse extends the head and neck
c. Larynx or pharynx or both
d. First heard on inspiration
e. Severe obstruction if heard on both inspiration and expiration
f. Sound character: Inspiratory stridor (loud "snore")
g. Upper airway narrows
h. Opposite walls oscillate between barely open and closed positions

J. Inadequate gas exchange
1. Respiratory rate (RR) greater than 18-22 in cool environment
2. No evidence of pain, excitement, metabolic dysfunction
3. Foals normally have more pronounced breathing pattern compared with adults

K. Coughing
1. Deep: Lower airway disease
2. Paroxysms of coughing
3. Hyperirritable airways (RAD, COPD)
4. Associated with eating: COPD
5. Laryngeal-pharyngeal irritation
6. Bronchoconstriction, coughing
7. Mechanoreceptors
a. Stretch
b. Unmyelinated C fibers
c. Irritant

L. Thoracic auscultation: Anatomic landmarks
1. Tuber coxae: 17th intercostal space (ICS)
2. Midthorax: 13th ICS
3. Point of shoulder: 11th ICS
4. Elbow: 6th ICS

M. Airway auscultation
1. Upper
a. Detectable with the unaided ear
b. Loudest on inspiration
c. Not as loud on expiration

2. Lower
a. Usually only detected with aid of stethoscope
b. Inspiratory or expiratory

3. High pitched wheezing: COPD (especially expiratory)
4. Mucus clicking (bronchial secretions)
a. Upper respiratory tract (URT); usually inspiratory
b. Snoring

5. High-pitched squeaking
a. Laryngospasm
b. Bronchospasm

6. Flutterings, gurglings: Exudate in URT
7. Rattling: Soft palate displacement
8. Stertorous breathing
a. Pharyngeal narrowing
b. Collapsed walls
c. Edema
d. Cysts

9. Unilateral stertorous breathing: Sinus

N. Lung sounds
1. Crackles
a. Bubbles
b. Moist: As rales
c. Crackles (inspiratory and expiratory): Explosive equalization of gas pressure in airways when a closed airway suddenly opens

2. Wheezes
a. "Continuous" sounds compared with crackles
b. Usually last longer than 200 to 400 milliseconds and have a musical quality
c. Also known as ronchi-ronchus
d. Single or multiple
e. Inspiration or expiration
f. Oscillation of opposite walls of bronchus when narrowed to the point of closure (vibrating reed)
(1) Airway edema
(2) Secretions
(3) Endobronchial tumors
(4) Extrinsic compression of an airway

g. Pleural friction rubs
(1) Pleural
(2) Loudest at end inspiration
(3) Variable in horses

O. Abnormal sounds
1. Upper airway obstruction
a. Inspiratory stertor: Low-pitched sounds, nostrils flare, and thorax expands
b. Reduced passage of air (usually unilaterally)

2. Lower airway
a. Crackles
b. Wheezes
c. Squeaks
d. No air movement

P. Assessment
1. Rebreathing bag
a. Causes horse to take bigger breaths
b. Increases air flow (more airways utilized)
c. Improves chance of detecting abnormalities

2. Clean garbage bag or rectal sleeve
3. Hold off the nostril
4. Pulmonary function setup

PREMATURITY AND DYSMATURITY

I. Lung failure
A. Surfactant: Least common reason
B. Hypoventilation due to prematurity (Figure 45-1)

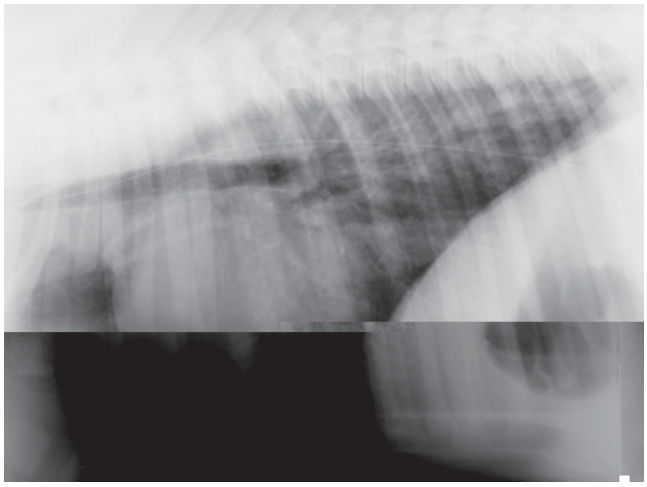


Figure 45-1 Right lateral radiograph of a premature foal. A diffuse increased soft tissue opacity partially silhouettes the pulmonary blood vessels (interstitial pattern). This diffuse interstitial lung pattern was caused by prematurity and resolved with no treatment. A tube with a radiopaque marker is present in the esophagus. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

1. Compliant chest wall
2. Weak muscles
3. Stiff lungs
4. Poor control of pulmonary vasculature
5. Mismatching
6. Shunting
7. Lateral recumbency
8. Atelectasis
9. Pulmonary edema

II. Premature/dysmature foals require
- A. Intranasal oxygen
- B. Positional support
- C. Some require
 1. Mechanical ventilation
 2. Criteria for using oxygen therapy
 - a. Pa_{O_2} less than 55 to 60 mm Hg in lateral recumbency
 - b. Increased RR
 - c. Labored respirations
 - d. Increased respiratory and abdominal muscle activity
- D. Oxygen toxicity: 100% O_2 for prolonged periods
- E. Pulmonary edema, lack of surfactant production, tracheal irritation

INFECTIOUS DISEASES

I. Gram-negative bacteremia with pneumonia (septic foals)
- A. Foals younger than 1 week of age
- B. Risk factors
 1. Prematurity
 2. Gestational age greater than 365 days
 3. Failure of passive transfer
 4. Hypoxemic ischemic encephalopathy (dummy foal)
 5. Maternal factors
 - a. Neonatal isoerythrolysis
 - b. Unsanitary foaling environment
 - c. Adverse climatic conditions
- C. Gram-negative bacteremia with pneumonia
 1. *Eschericia coli*
 2. *Actinobacillus* spp.
 3. *Klebsiella* spp.
 4. *Enterobacter* spp.
 5. *Pseudomonas* spp.
 6. *Salmonella* spp.
 7. Mixed infections (>50 % of foals)
 8. Most common site of entry is the gut
- D. Clinical signs neonatal septicemia
 1. Early
 - a. Lethargy
 - b. Reduced affinity for mare
 - c. ↓ Sucking activity
 - d. Fever
 - e. Hypothermia
 - f. Tachypnea
 2. Advanced
 - a. Injected mucous membranes
 - b. Petechiation
 - c. Anterior uveitis
 - d. Diarrhea
 - e. Coma, convulsions
 - f. Tachycardia
 - g. Respiratory distress
- E. Clinical pathology
 1. Immunoglobulin G (IgG) less than 400 mg/dL
 2. Neutropenia with left shift (some may have neutrophilia). Fibrinogen ↑
 3. Hypoglycemia (less than 80 mg/dL)
 4. Hypoxemia (Pa_{O_2} less than 70 mm Hg)
- F. Imaging techniques
 1. Radiography
 2. Pulmonary infiltrate
 3. Serial radiographs are helpful
- G. Ultrasound
 1. With or without pleural fluid
 2. Cardiac abnormalities
 3. Comet tails
 4. Alveolar infiltrate
 5. Fluid
 6. Inflammatory cells
- H. Treatment
 1. Appropriate antimicrobials
 2. Fluid therapy: Correct dehydration, hypoglycemia, acidosis; maintain renal perfusion
 3. Nutritional support
 4. Nursing care
 5. Plasma
 6. Respiratory support: Oxygen therapy
 7. Financial commitment
 8. Antimicrobial considerations
 - a. Broad spectrum
 - b. Parenteral vs. enteral
 - c. Affordability
 - d. Efficacy
 - e. Potential for resistance on farm
 - f. β-lactams
 - g. Aminoglycosides
 - (1) Gram: Aerobes

(2) Not effective against anaerobes or in abscesses
(3) Adverse effects: Tubular damage, neuromuscular blockade
(4) Recommend pharmacokinetic monitoring

h. Third-generation cephalosporins
(1) Broad-spectrum activity
(2) Bactericidal
(3) Effective against resistant organisms
(4) Exception: Aminoglycoside-resistant organisms
(5) Hepatic metabolism
(6) Limited intracellular penetration
(7) Adverse effects: May cause diarrhea, renal tubular damage in hemoconcentrated patients

i. Potentiated sulfas: Tribrissen, Bacterim, Septra, Uniprim, generics
(1) Nontoxic
(2) Broad-spectrum; resistance may develop to *R. equi*
(3) High volume of distribution
(4) Prolonged post-antibiotic effect for gram-negative organisms
(5) Poor against anaerobes
(6) Poor abscess penetration
(7) Adverse effects: Hypersensitivities, folate antagonism, diarrhea

j. Fluoroquinolones: Enrofloxacin (Baytril) and ciprofloxacin
(1) Broad-spectrum: Rapidly bacteriacidal
(2) Active against most isolates
(3) Poor against anareobes
(4) Wide tissue distribution
(5) Renal secretion
(6) Toxic effect on growing cartilage
(7) Not recommended for use in foals!

k. Imipenem
(1) β-lactam antibiotics called carbapenems
(2) Very wide spectrum of activity in vitro
(3) Stable in the presence of bacterial β-lactamases
(4) Cilastatin
(5) Blocks the renal metabolism of imipenem

II. Equine herpes virus type 1 (EHV-1): Adult bronchopneumonia
A. Interstitial pneumonia
B. Bronchopneumonia
C. Lymphoid depletion
D. In utero infections or post-foaling. Difficult to make diagnosis antemortem
E. Testing for EHV-1 and equine herpes virus type 4 (EHV-4): Antigen virus detection
1. Nasal swabs
2. Citrated blood samples (monocytes): Buffycoat polymerase chain reaction (PCR)
3. PCR can distinguish between EHV-1 and EHV-4
4. Serology requires paired samples (4× increase = infection)
5. Complement fixation
6. Hemagglutination inhibition
7. Virus neutralization
8. Enzyme-linked immunosorbent assay (ELISA)
9. Radial hemolysis: Sensitive test used in outbreak situations

III. Other viruses
A. Equine influenza: Antigen tests
1. Viral culture and isolation: Least sensitive
2. PCR takes 48 hours: Directigen Flu A, stall side antigen test (Becton Dickinson)
3. Serology: Requires paired samples
4. Complement fixation
5. Hemagglutination inhibition
6. Virus neutralization
7. ELISA
8. Radial hemolysis: Sensitive test used in outbreak situations
B. Respiratory syncytial virus (RSV)
C. Adenovirus

IV. *R. equi* (snotty-nosed foals): Disease of the lower respiratory tract that manifests with mucopurulent nasal exudate
A. Soil-based saprophytic organism, pleomorphic rod-shaped bacteria: Causes suppurative bronchopneumonia in 2- to 6-month old foals. An emerging disease in acquired immune deficiency syndrome patients
B. Clinical signs
1. Advanced
a. "Acute or chronic" form
b. Suppurative bronchopneumonia
c. Extensive cavitating abscessation
d. Suppurative lymphadenitis internal or external
e. Abdominal involvement
f. Osteomyelitis
g. Hypopyon
h. Immune-mediated response
i. Polysynovitis
j. Immune-mediated response: Atypical presentations
2. Subclinical
a. With or without fever
b. With or without lung abscesses
c. Unthriftiness
3. Subacute
a. Minimal abscessation
b. Rapid development
c. Acute interstitial pneumonia
d. Red, hepatized lung
e. Extrapulmonary forms
f. Enteritis
g. Peritonitis
h. Osteomyelitis
i. Submandibular lymphadenitis
j. Mesenteric lymphadenitis
C. Histopathology: Suppurative lymphadenitis
D. Diagnostics
1. Thoracic radiographs (Figure 45-2)
a. Usually require 1000 ma machine for adults
b. Smaller units for skinny horses, foals; URT, adults, tracheal disease
2. Serology: Does not correlate with clinical disease

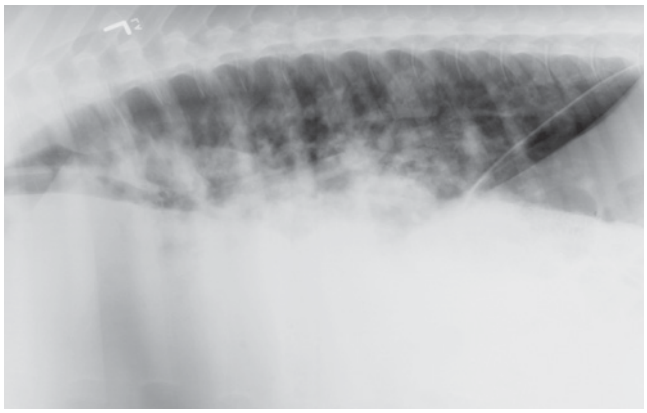


Figure 45-2 Left lateral radiograph of a 3-month-old foal with pneumonia caused by *Rhodococcus equi* infection. In the ventral portions of the lung is an alveolar lung pattern. In the caudodorsal portions of the lung multiple soft tissue nodules can be seen, the largest of which is cavitated. The nodules are caused by abscess formation. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

E. Diagnosis: Early Cases
 1. Clinical signs: Fever, rapid respiratory rate
 2. Clinical pathology: Increased fibrinogen, elevated neutrophil count, elevated platelet count
 3. TTW: Gram stain, culture, sensitivity
 4. Thoracic imaging: Radiographs, ultrasound

F. Early recognition of disease
 1. Close monitoring of foals
 2. RR and rectal temps
 3. Complete blood cell count (CBC)
 4. Ultrasonography scan
 5. TTW
 6. Gram stain or culture
 7. Survey farm or ranch
 8. Culture soil, manure, identify carrier mares or foals
 9. PCR
 10. Differentiate between virulent and avirulent strains

G. Prevention: Environmental control
 1. Decrease animal numbers in loafing areas
 2. Improve hygiene practices
 3. Manure removal (off the farm)
 4. Eliminate dusty paddocks
 5. "Every-other-year" phenomenom
 6. Prevention: Hyperimmune plasma

H. Treatment
 1. Antimicrobial options
 a. Erythromycin phosphate: 25 mg/kg orally (PO) every 12 hours
 b. Erythromycin estolate or stearate: 25 mg/kg PO every 8 hours
 c. Trimethoprim/sulfa 20 mg/kg PO every 12 hours + rifampin 5 to 10 mg/kg PO every 12 hours
 d. Azithromycin (Zithromax) + rifampin: 10 mg/kg PO every 24 hours for 5 days, then every other day until resolution of disease
 e. Clarithromycin (7.5 mg/kg twice daily) + Rifampin
 2. Adverse side effects associated with antimicrobial treatment
 a. Hyperthermia associated with erythromycin administration
 b. Acute colitis in mares (foals on treatment)
 c. Enterocolitis in foals
 3. Additional supportive care
 a. Antiinflammatories: Nonsteroidals, ketoprofen, dimethyl sulfoxide (DMSO), steroids, short acting for advanced cases
 b. Bronchodilators: Clenbuterol, albuterol, terbutaline, aminophylline
 c. Oxygen therapy
 d. Intravenous (IV) fluids in advanced cases
 4. Treatment plan
 a. Antimicrobials
 b. Continue for 2 to 3 weeks longer than when clinical signs resolve
 c. Keep away from other foals (especially very young foals)
 d. Identifying endemic farms
 e. Client education
 f. Necropsy
 g. Culture and sensitivity of abscesses
 h. Designing cost vs. benefit of program: Loss due to morbidy and mortality vs. cost of testing

V. Strangles
 A. Easily transmitted infectious disease
 B. Occurs worldwide in horses
 C. Caused by bacterium: *Streptococcus equi equi*
 D. Occurs in young horses; aged 6 months to 2 years most susceptible
 E. Can occur in any age lacking immunity from previous infection or vaccination
 F. Not communicable to humans
 G. Clinical signs
 1. Lymph node abscessation usually of the head and neck
 2. High fever
 3. Thick yellow discharge from nostrils and eyes
 4. Swollen lymph nodes of the head and neck
 5. Draining exudate
 6. Difficulty in swallowing, often with an extended neck
 7. Fever up to 106° F
 8. Depressed with no appetite
 9. Coughing
 H. Epidemiology
 1. Highly contagious
 2. Easily transmitted through bacteria found in discharges from an infected animal
 3. Coughing aerosolizes the bacteria
 4. Fomites (usually people) carry it from horse to horse
 5. Incubation period 3 to 12 days
 6. Clinical signs last about 2 to 4 weeks
 7. Shedding may occur from 4 weeks to as long as 8 months after clinical signs resolve
 8. Affected animals should be isolated from unexposed horses for prolonged periods
 9. Recovered horses can become chronic carriers

10. Immunity lasts several years after recovery in most cases
11. Mortlaity rate is low, but morbidity rate is high

I. Treatment
1. Infected equine should be immediately isolated from other horses
2. Complete rest and nursing care should also be provided
3. Hot packs applied to abscesses may expedite healing
4. Affected equine should be fed soft, palatable feed if having trouble swallowing
5. Antimicrobials (penicillin) may be indicated for prolonged treatment in some cases
6. Prevention: Strangles can be prevented from spreading by taking the following precautions:
 a. Vaccinate equine if endemic in the herd or on the farm
 b. Isolate new equine for 2 to 3 weeks before introducing them to the herd
 c. Check rectal temperatures twice daily for evidence of fever. Because fever usually develops two days before bacteria shedding, early detection of fever may prevent further transmission
 d. Any newly isolated equine with a nasal discharge should be examined by a veterinarian. Prompt diagnosis is important to prevent additional spread
 e. Stop movement on and off the infected premises
 f. Disinfect stalls, water troughs, tack, and grooming utensils
 g. Do not mix equipment between infected equine in isolation and noninfected equine
 h. Handle infected equine only after handling noninfected equine
 i. Assign one person to handle affected equine and to avoid contact with healthy equine
 j. Wash hands, arms, footwear after handling infected animals
 k. Vaccination (See Chapter 43, Preventive Medicine)

OBSTRUCTIVE PULMONARY DISEASE IN HORSES

I. Syndromes
A. COPD
B. Summer pasture associated obstructive pulmonary disease (SPAOPD)
C. RAD
D. Also known as broken wind, heaves, equine asthma, obstructive pulmonary disease (OPD)

II. Clinical signs
A. Exercise intolerance
B. Expiratory dyspnea
C. Chronic purulent nasal discharge
D. Cough
E. Increased respiratory rate
F. Weight loss
G. Flared nostrils
H. Exaggerated abdominal expiration
I. Heave line
J. Wheezes and crackles

III. RAD
A. Laboratory testing
1. Normal blood work
2. Endoscopy: Mucus or mucopus
3. TTW or BAL
 a. Increase in neutrophils
 b. Increase in mucus
4. Radiographs (Figure 45-3)
 a. Bronchitis, bronchiolitis
 b. With or without interstitial pneumonia (secondary)
5. Blood gas: Normal unless in distress
 a. Increased Pa_{CO_2}
 b. Decreased Pa_{O_2}
6. Atropine challenge test: Immediate marked improvement in breathing effort

B. Pathology findings
1. Bronchiolitis
2. Epithelial hyperplasia
3. Mucus plugging of airways
4. Neutrophilic, lymphocytic, plasmacytic infiltrate
5. Peribronchial fibrosis

C. Pathophysiology
1. Increased airway resistance
2. Decreased dynamic compliance
3. Diffuse lower airway obstruction
 a. Mucus plugging
 b. Bronchoconstriction (airway smooth muscle)
4. Airway hyperresponsiveness

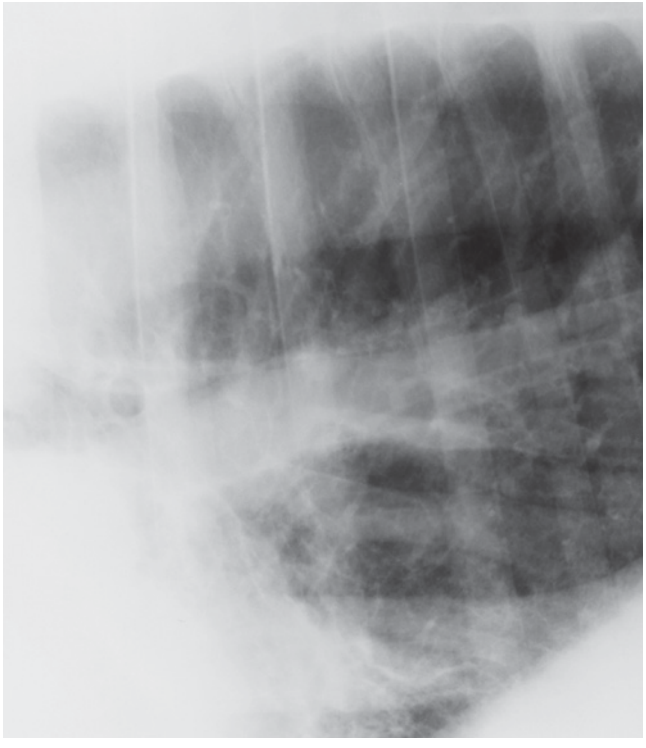


Figure 45-3 Right lateral radiograph of an adult horse with chronic bronchitis and a bronchial pattern. Note the increased opacity that follows the airways, creating parallel lines and rings. (From Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.)

D. Causes
 1. Allergens
 a. Specific molds
 b. Thermophilic molds
 c. Actinomycetes
 2. Hyperresponsive animals are hyperresponsive to nonspecific stimuli (e.g., histamine) during periods of hyperreactivity
 a. Suggests that inflammation in one area may serve to "prime" other areas
 b. Respiratory irritants include cotton and grain dust, irritating fumes, smoke, gases (ammonium, HCl), biological enzymes, proteins (urine, poultry dander, mites), anhydrides, metal salts, nitrous oxide
 c. Viral and bacterial infections include influenza, RSV (humans), rhinovirus, and herpes virus
 d. Hyperresponsiveness lasts for 4 to 8 weeks (human)

E. Pathogenesis of bronchial hyperresponsiveness
 1. Systemic and local inflammation
 2. Inflammatory infiltrate
 3. Changes in epithelial morphology
 4. Changes in neurogenic control
 5. Release of additional mediators
 6. Inflammatory cell Infiltrate
 7. Lymphocyte population
 8. CD5+ and CD8− subpopulations increase
 9. Perivascular and peribronchial immonuglobulin A and IgG
 10. Mast cells
 11. Bronchial clefts and intracellularly

F. Inflammation
 1. BAL fluid: COPD (recurrent airway obstruction) contains large number of neutrophils (Figure 45-4)
 2. Individual animal variability
 3. Large number of neutrophils does not correlate with more severe disease
 4. Proteases, reactive oxygen species (ROS), other mediators

G. Treatment of COPD and RAD
 1. Environmental control
 2. Minimize dust, antigens
 3. Pharmacologic intervention
 4. Bronchodilators
 5. Mucolytics
 6. Antiinflammatories
 a. Dexamethasone: Decrease by 10% every three treatments
 b. Prednisolone
 (1) 2.2 mg/kg PO × 7 to 10 days
 (2) 1.1 mg/kg PO × 7 to 10 days
 (3) 0.5 mg/kg PO × 7 to 10 days
 c. Metered dose inhalers
 (1) Not effective for 2 to 3 days
 (2) Beclomethasone (3750 ug twice daily)
 (3) Fluticasone (2 ug twice daily)
 (4) DMSO: Unknown efficacy
 d. Bronchodilators
 (1) Parasympatholytics
 (2) Muscarinic receptor antagonists
 (3) Glycopyrrolate
 (4) Atropine
 (5) Sympathomimetics: β_2-adrenoreceptor agonists such as clenbuterol, albuterol
 (6) Ipratropium bromide
 (7) Methylxanthine derivatives: Aminophylline
 (8) Aeromask
 (a) Bronchodilators: Buterols
 (b) Steroid therapy: Fluticasone, betamethasone
 (c) Inhibitors of mast cell degranulation: Cromalyn sodium
 (d) Interferon: Interferon-α, oral but destroyed in the stomach. Higher doses are less effective. There are adverse side effects with IV formulations

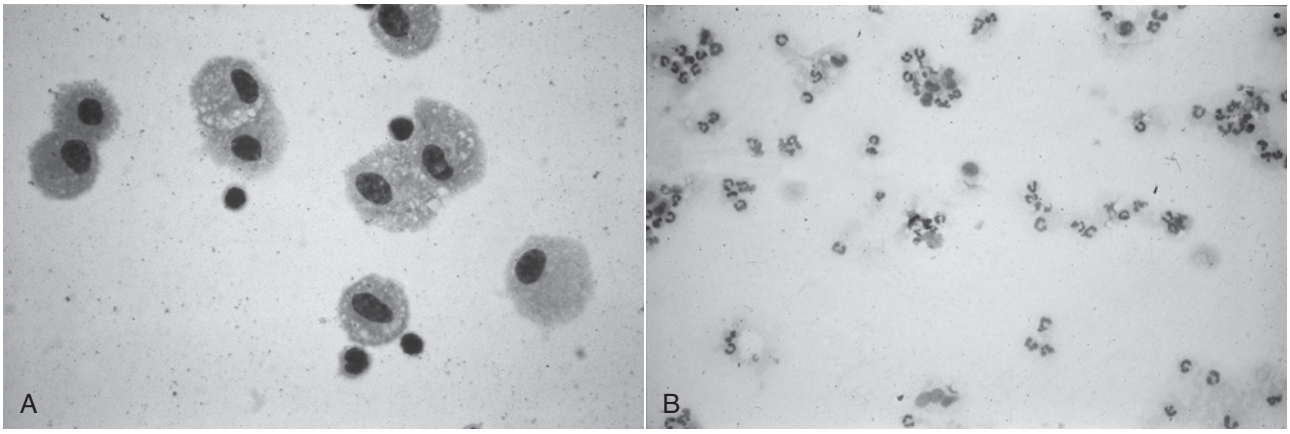


Figure 45-4 **A,** Normal cytologic results from a bronchoalveolar lavage sample obtained from a healthy horse. Mature macrophages (foamy cytoplasm) and dark-staining lymphocytes make up the predominant cell types. **B,** Sample obtained from a horse suffering from recurrent airway obstruction. Note the predominance of neutrophils (N <15%) that make up most of the leukocyte population on bronchoalveolar lavage cytologic examination. (From Bertone J. *Equine Geriatric Medicine and Surgery.* St Louis, 2006, Saunders.)

VETERINARIAN'S ROLE IN DISEASE OUTBREAKS

I. Obligation to the owner or trainer
 A. Well-being of animal
 B. Financial considerations
 C. Prognosis
II. Advocate for the horse
III. Advocate for other horses (trainers, owners)
 A. Barn, shedrow
 B. Herd
 C. Racetrack area
 D. State → intrastate and interstate transport and spread
IV. Uphold federal and state laws
 A. Disease reporting
 B. Racetrack practice
 C. Respiratory outbreak in training facility
V. Acute respiratory disease
 A. Mucopurulent nasal discharge
 B. Inappetence
 C. Fever
 D. Lethargy
 E. Depression
VI. Epidemiologic investigation of viral and bacterial disease
 A. Where and when a condition occurs?
 B. How much is occurring?
 C. Who is affected?
 D. Search for primary cause
 E. Means of control
 F. Efficacy of control measures
 G. Epidemiologic Investigation
 1. Age
 2. Sex
 3. Pattern of spread
 4. Geographic distribution (map)
 5. Attack rate (number of new cases)
 6. Prevalence (total number of cases over time)
 7. Morbidity rate (number affected, number at risk)
 8. Mortality rate (number of deaths, number at risk)
 9. Veterinarian's recommendations
 a. Affected patient
 b. Diagnosis, treatment, prognosis
 c. Response to treatment
 d. Exposure to other equids
 e. Disease containment
 f. Infection control
 H. Patient treatment and diagnostics
 1. Diagnostics
 a. CBC
 b. Serum chemistry profile
 c. Serology
 d. Nasal, pharyngeal swab
 e. TTW
 f. Necropsy
 2. Treatment
 a. Broad-spectrum antimicrobials
 b. Antiinflammatory drugs
 c. Fluid replacement
 d. Nutrition
 3. Diagnostic tests
 a. Serology
 (1) Equine viral arteritis (EVA)
 (2) EHV-1 and EHV-4
 (3) Equine influenza 1 and 2
 (4) Adenovirus
 (5) Equine rhinovirus
 b. Virus isolation
 (1) Nasal-pharyngeal swab
 (2) Citrated blood (herpes, EVA)
 c. TTW: Bacterial culture
 d. Necropsy: Submit bronchial lymph nodes, liver, spleen, blood
VII. Reportable equine respiratory diseases
 A. African horse sickness
 B. EVA
 C. Vesicular stomatitis
 D. Any other disease condition that might seriously threaten the welfare of the horse populations of the state

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.
Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed. St Louis, 2009, Saunders.
Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2009, Mosby.
Thrall DE. *Textbook of Veterinary Diagnostic Radiology,* 5th ed. St Louis, 2007, Saunders.

46 CHAPTER

Restraint

Rebecca S. McConnico

GENERAL CONSIDERATIONS

I. Most important aspect of the equine physical examination
II. Improper restraint will result in a poor examination
III. Horse may:
 A. Kick
 B. Bite
 C. Rear
 D. Strike
IV. Safety is the most important aspect
 A. Veterinarian: No job is worth doing if you get hurt
 B. Handler (owner, manager, or assistant): The veterinarian must trust the handler's restraint capability. Be aware of legal considerations if the handler or the animal is injured as a result of restraint techniques
 C. It is safest to use the most minimal restraint possible
 D. Restraint does not need to equate to physical force
 E. What typically works for one horse will not necessarily work for another. Draft horses, although larger, may need little restraint compared with a young 2-year-old thoroughbred horse
 F. Approach the horse from the left side
 G. Safest place to work is by the shoulder area
 H. Handler and examiner should be on the same side of the horse

CATEGORIES OF RESTRAINT (CAN BE USED ALONE OR TOGETHER)

I. Physical
 A. Minimum restraint required: Halter and lead rope
 1. Never attempt to do a physical examination without a halter and lead rope in place and someone holding the horse
 2. Do not wrap a lead around your hand, arm, or any other body part
 3. Do not tie a horse unless you know it is accustomed to being tied
 B. Chain over the nose or under the upper lip may provide additional restraint. This method is often used on young horses or stallions
 C. Twitching
 1. Twitching with hand (grasp skin with hand and pull/twist with a firm grip) (Figure 46-1)
 2. Neck or shoulder twitch
 3. Nose twitch: Use a chain or nylon rope twitch, pull upper lip through a loop of chain or rope, and twist firmly
 4. Ear twitch: Grasp ear with hand and twist firmly
 D. Twitching devices
 1. Different types
 a. Wood with rope: Less severe than others listed below
 b. Wood with chain
 c. Metal
 2. Applying twitch: Firmly grasp muzzle with fingers through loop, place loop over end of nose, and twist the stick. May be tightened or loosened as appropriate (Figure 46-2)
 3. Considerations
 a. Never let go of twitch: Can swing and injure you, the handler, or the horse
 b. Size counts: The longer the twitch, the more control (i.e., more leverage)
 c. Do not leave twitch on too long; may cause damage or become ineffective
 d. Do not put twitch device on the ear; add chemical restraints if needed
 E. Lifting a limb
 1. May be helpful to allow examination of weight-bearing limbs
 2. Use with caution; horses are stronger than human handlers
 F. Crossties
 1. Appropriate for grooming but generally crossties or tying a horse is not recommended while conducting a physical examination
 2. Definitely not for painful or bothersome procedures
 G. Stocks
 1. Very helpful for colic evaluations (rectal exams) and reproductive evaluations
 2. Not foolproof: Horses may try to jump out or go down
 H. Rectal exam restraint considerations: It is unsafe to use the half door because it may protect the examiner from getting kicked, but if a horse goes down, the examiner loses arm
 I. Foal restraint
 1. Foal restraint is very different from adult equine restraint
 2. Foals lack training and experience
 3. Commands, techniques, and devices used in adults are often ineffective and potentially dangerous to use with foals



Figure 46-1 Grasp as much skin on the horse's shoulder as possible with one or both hands. (From Sheldon CC, Topel J, Sonsthagen TF. *Animal Restraint for Veterinary Professionals.* St Louis, 2006, Mosby.)



Figure 46-2 Grasp as much of the horse's upper lip with your left hand as possible, pressing the bottom edges together to protect the delicate inner surface. (From Sheldon CC, Topel J, Sonsthagen TF. *Animal Restraint for Veterinary Professionals.* St Louis, 2006, Mosby.)

4. The best method of foal restraint
 a. Arm in front of chest and arm behind rump while grabbing tail
 b. Never pull on foal's head
 c. Never tie a foal

II. Verbal restraint
 A. Talking to horses can be an effective means of restraint
 B. Use a soothing, reassuring tone
 C. Many times, a sharp authoritative tone accompanied by a tug on the lead rope may help keep a fidgety horse in place

III. Chemical restraint
 A. General considerations
 1. Try to perform a physical exam before using chemical restraint
 2. Chemical restraint can be used alone or with other techniques or devices. Consider the animal's weight, age, and health and the procedure.
 B. Indications
 1. To calm the horse and safely manage medical evaluation or treatment
 2. Can minimize further injury to the patient
 3. Can prevent human injury
 C. Sedative agents that may be used
 1. Acetylpromazine (0.02 to 0.08 mg/kg administered intravenously [IV])
 2. Xylazine (0.5 to 0.75 mg/kg IV)
 3. Detomidine (5 to 20 mcg/kg IV) with added butorphanol (0.01-0.02 mg/kg IV). Yohimbine (0.1 to 0.15 mg/kg IV) may be indicated for α-2 agonist reversal in the event of significant bradycardia and hypotension
 D. Adverse response to sedation and tranquilization
 1. Hypotension
 2. Decrease gastrointestinal motility
 3. Exacerbate cardiovascular shock
 E. For maximum restraint of sick or injured horses, the following are recommended:
 1. Detomidine sedation (5 to 20 μg/kg) followed by butorphanol (0.01 to 0.02 mg/kg IV). Short-acting general anesthesia may be necessary
 2. "Triple-drip" method (guaifenesin/ketamine/detomidine)
 a. Guaifenesin 50 mg/mL in 5% dextrose in water
 b. Ketamine 2 mg/mL
 c. Detomidine 5 μg/kg
 d. Horse or pony is premedicated with detomidine (10 to 20 μg/kg) and then induced with detomidine (10 μg/h) and ketamine (2 mg/kg) IV bolus; and then maintained on the triple drip (2 mL/kg/h). If a 15 drop/mL infusion set is used, the rate will be one drop per second of the triple-drip solution to maintain the horse under general anesthesia. Recovery usually occurs 35 to 40 minutes after discontinuing the infusion. It is critical to provide a safe area for recovery, which may add to the challenge of a disaster flood environment

Supplemental Reading

Reed SM, Bayly WM, Sellon DC. *Equine Internal Medicine,* 2nd ed. St Louis, 2004, Saunders.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2008, Mosby.

47 CHAPTER

Surgery

Colin F. Mitchell and Britta S. Leise

UPPER RESPIRATORY TRACT DISORDERS

I. Disorders of the guttural pouch
 A. Anatomy of the guttural pouch
 1. Two pouches are present, one on the left and one on the right. Each pouch has two compartments that are separated by the stylohyoid bone
 a. Medial compartment: Internal carotid artery (ICA), cranial cervical ganglion, sympathetic trunk, cranial nerves (CN) IX (glossopharyngeal), X (vagus), XI (accessory), XII (hypoglossal), pharyngeal branch of the vagus, cranial laryngeal nerve
 b. Lateral compartment: External carotid artery, maxillary artery, CN VII (facial nerve)
 2. The opening (plica salpingopharyngeal) to the guttural pouch can be seen on upper respiratory tract endoscopy and is seen in the pharynx as two slits on lateral walls
 B. Guttural pouch tympany
 1. Causes, signalment
 a. Inflammation or abnormal, redundant thickening of the plica salpingopharyngea that allows air to be trapped in guttural pouch. Typically this is a unilateral condition, but it can be bilateral
 b. Age: Typically less than 6 months old
 c. Fillies tend to be overrepresented
 2. Clinical signs: Respiratory stridor, dyspnea secondary to compression of the pharynx, marked nonpainful swelling caudal to the ramus of the mandible, dysphagia, aspiration pneumonia in severe cases
 3. Diagnosis
 a. Endoscopy: Collapse of pharynx; air is removed if guttural pouch entered
 b. Radiographs: Air-filled distension of guttural pouch; need dorsoventral (DV) view to determine whether condition is bilateral
 4. Treatment
 a. Prolonged catheterization of guttural pouch and antibiotics
 b. If unilateral, surgical fenestration of medial septum of affected pouch into normal pouch. This technique can be done transendoscopically with a laser or via a modified whitehouse approach
 c. Create a salpingopharyngeal fistula (new pharyngeal opening)
 5. Prognosis and complications
 a. Depends on bilateral or unilateral involvement: Good if unilateral treated surgically; worse if bilateral
 b. Worse prognosis (guarded) if aspiration pneumonia is present
 c. Disorder could recur if new fistula or fenestration closes
 C. Guttural pouch empyema
 1. Causes, signalment
 a. Usually secondary to infection
 (1) Most common bacteria isolated is β-hemolytic streptococcus (*Streptococcus equi* var. *equi*, *Streptococcus equi* var. *zooepidemicus*)
 (2) Rupture of retropharyngeal lymph nodes into pouch
 (3) Other causes include middle ear infections, fractures of stylohyoid bone, or pharyngeal trauma
 (4) Can be unilateral or bilateral
 b. Chronic infections may lead to desiccation of exudate and formation of chondroids
 c. Typically younger horses
 2. Clinical signs
 a. Bilateral or unilateral nasal discharge (typically nonodorous)
 b. Swelling with or without pain caudal and distal to ramus of mandible
 c. Lymphadenopathy, lymphadenitis
 d. Dysphagia secondary to neuritis
 e. Dyspnea secondary to pharyngeal collapse
 f. Facial nerve paralysis secondary to CN VII neuritis
 3. Diagnosis
 a. Endoscopy: Purulent exudate or chondroids present in guttural pouch
 b. Radiography: Fluid line present within air-filled guttural pouch; presence of radiopaque chondroids
 c. Complete blood cell count (CBC): Leukocytosis, increased fibrinogen
 d. Culture and sensitivity of purulent exudate or chondroids. Usually *Streptococcus*
 4. Treatment
 a. Lavage of guttural pouches through the nasal passage

(1) Done via catheter placed into the pouch endoscopically guided. Catheters can be left in place for several days.
(2) Treatment with antibiotics when flushing is common due to the risk of aspiration of purulent material during the flush

b. Surgical opening of guttural pouches to remove chondroids or allow for drainage. Various approaches to opening the pouch to allow for drainage
(1) Hyovertebrotomy: Dorsolateral approach at caudal aspect of pouch; does not allow for good ventral drainage
(2) Viborg's triangle: Landmarks are sternomandibularis tendon, vertical ramus of mandible, and linguofacial vein. Allows for good ventral drainage and avoids neurovascular structures
(3) Modified Whitehouse: Approach is ventral and medial to linguofacial vein alongside larynx. Allows for good ventral drainage and best access to pharyngeal opening

5. Prognosis and complications: Prognosis good. Complications: Aspiration pneumonia from aspiration of lavage fluid while sedated; if concurrent retropharyngeal lymph node enlargement is present, obstruction of the upper airway may require tracheotomy to allow horse to breathe

D. Guttural pouch mycosis
1. Causes and signalment
a. Usually due to *Aspergillus*; adult horses, any breed, typically unilateral
b. Occurs on dorsocaudal wall of medial or lateral compartment; can erode through the mucosa, affecting blood vessels and nerves
2. Clinical signs
a. Epistaxis: Hallmark sign, mild to severe; may increase in severity with each episode or may occur acutely with death. Source of hemorrhage is typically the ICA if in medial compartment or maxillary artery (branch of the external carotid artery) if in lateral compartment
b. Nasal discharge: Serous to mucoid and may be blood tinged
c. Other signs include dysphagia, Horner syndrome, facial paralysis, laryngeal paralysis, head shaking, blindness
3. Diagnosis
a. CBC (leukocytosis, anemia)
b. Endoscopy: Blood around guttural pouch opening or within pouch; diphtheric plaque present on caudal wall of pouch over nerves and vessels
c. Radiographs: Fluid in guttural pouch; angiogram of ICA may show aneurysms of arterial wall within the guttural pouch
4. Treatment
a. Medically with systemic and topical antifungal drugs; however, may not cure and while treating, potential risk of fatal hemorrhage from erosion into vessels
b. Surgical occlusion (ligation or balloon catheterization) of affected vessels: Ligation of ICA if medial compartment affected; ligation of the external carotid artery if lateral compartment (maxillary artery) affected. Ligation might not stop bleeding because of retrograde flow of blood
5. Prognosis
a. Sequelae include fatal hemorrhage, pharyngeal fistula, erosion into other guttural pouch, osteitis of stylohyoid bone
b. Depends on successful occlusion of the affected vessels
(1) Good if bleeding is stopped and kept under control
(2) Grave if bleeding cannot be controlled
(3) Poor if concurrent laryngeal hemiplegia or dysphagia is present
c. Complications
(1) Unsuccessful response to antifungal therapy
(2) Hemorrhage during surgery
(3) Unable to occlude the vessels effectively and bleeding persists
(4) Blindness related to ligation-occlusion of vessels
(5) Neurologic deficits (dysphagia, laryngeal or facial paralysis, or Horner syndrome) can improve following therapy but will not resolve completely

E. Temporohyoid osteoarthropathy
1. Cause and signalment
a. Progressive infection of middle or inner ear or hematogenous spread to temporohyoid joint
b. Results in osseous proliferation (of stylohyoid bone near area of insertion of petrous temporal bone), ankylosis of temporohyoid joint, and possible pathological fracture of area
2. Clinical signs: Head shaking, ear rubbing, facial nerve paralysis, head tilt (toward affected side), ataxia, nystagmus (slow component towards affected side)
3. Diagnosis: Radiographs, endoscopy, computed tomography (CT)
4. Treatment: Antimicrobials, antiinflammatories, ceratohyoidectomy
5. Prognosis
a. Poor to grave, especially if facial nerve paralysis is present
b. Surgical therapy is useful in patients that do not respond to conservative treatment, but neurologic deficits often will not resolve entirely

II. Diseases of the epiglottis
A. Epiglottic hypoplasia

1. Cause and signalment: Occurs in racing thoroughbreds because of shortened epiglottis (in thoroughbreds, less than 7 cm long). Will predispose to dorsal displacement of soft palate (DDSP) and epiglottic entrapment
2. Clinical signs of poor performance
3. Diagnosis
 a. Endoscopy: Flaccid, blunted appearing epiglottis; entrapment of epiglottis or DDSP. May require treadmill endoscopy
 b. Radiography: Lateral; can measure thyroepiglottic length
4. Treatment: Epiglottic augmentation
 a. Injection of Teflon on the ventral surface under the mucosa
 b. Typically combined with myectomy, tongue tie, or staphylectomy
5. Prognosis and complications
 a. Success is around 65% with injection combined with other treatments
 b. Can get granulomatous reaction or thickening around injection site

B. Epiglottic entrapment
1. Cause and signalment: Epiglottis becomes entrapped by redundant aryepiglottic fold; loose mucosa ventral to epiglottis flips up around edge of epiglottis. This fold obstructs airflow during expiration, leading to exercise intolerance
2. Clinical signs: Exercise intolerance, coughing, respiratory stridor (expiratory), dysphagia, nasal discharge
3. Diagnosis is by endoscopy
 a. Normal scalloped edge appearance of epiglottis is obscured by the aryepiglottic fold that entraps the epiglottis
 b. Ulceration is commonly present with chronic epiglottic entrapment
 c. Careful not to confuse with DDSP
 d. Intermittent DDSP can be present as well
4. Treatment
 a. Treat with antiinflammatories and rest
 b. Surgical treatment by transaction or resection aryepiglottic fold
 (1) Transection with a curved hook with blade: Performed via an oral approach (must displace soft palate); performed via nasal approach using endoscopy
 (2) Transection performed transendoscopically with laser: Must be very careful not to laser the epiglottis; not recommended for chronic ulcerative entrapment
 (3) Resection of aryepiglottic fold is performed through a laryngotomy approach
 c. Postoperatively, rest and antiinflammatories are also recommended
5. Prognosis and complications
 a. Prognosis is good; however, if chronic and changes to epiglottis are present, then return to full athletic function is guarded
 b. Complications: Damage to epiglottic cartilage, re-entrapment, displacement of soft palate

C. Epiglottic cyst
1. Cause and signalment
 a. Cysts are remnants of thyroglossal duct (lack of closure) that typically occur at ventral caudal base of epiglottis
 b. Any breed or age can be affected; not common
2. Clinical signs: Coughing, dysphagia, respiratory stridor, poor performance
3. Diagnosis
 a. Endoscopy: Cyst seen under epiglottis, with epiglottis tip abnormally placed point up; cyst may be partially hidden under the soft palate
 b. Radiography: Can be seen as a soft tissue mass under the epiglottis
4. Treatment: Surgical removal via laryngotomy approach; oral snare (once soft palate has been displaced)
5. Prognosis and complication: Prognosis good. Recurrence if entire cyst lining is not removed

III. Disorders of the larynx

A. Laryngeal anatomy
1. Laryngeal cartilages: Epiglottis, thyroid cartilage, cricoid cartilage, artyenoid cartilage (paired) with muscular and corniculate processes
2. Aryepiglottic fold connects corniculate processes of the arytenoids to ventral surface of epiglottis
3. From ventral aspect of corniculate process to floor of rima glottis (opening of larynx into trachea) are vocal cords. Fold of respiratory mucosa that makes a pocket from the vocal cord to side of rima glottis is known as laryngeal ventricles
4. Opening of larynx for maximal air flow down to lungs is controlled by cricoarytenoideus dorsalis. This muscle abducts arytenoids cartilages and is innervated by recurrent laryngeal nerve

B. Laryngeal hemiplegia
1. Etiology and signalment
 a. Caused by irreversible damage (distal axonopathy) to recurrent laryngeal nerve; causes dysfunction of cricoarytenoideus dorsalis muscle and inability for muscle to abduct corniculate process of arytenoid
 (1) Nerve damage can be idiopathic or secondary to perivascular injection surrounding jugular vein, abscessation of lymph nodes, or guttural pouch disease
 (2) 95% of cases are left-sided and idiopathic
 b. Failure of arytenoid to abduct results in turbulent airflow during respiration (both inspiratory and expiratory) and increased negative pressures during inspiration. Results in exercise intolerance and respiratory stridor (noise known as "roaring") particularly at high speeds
 c. Disorder is common in large horses, particularly draft horses, warmbloods and thoroughbreds

d. Typical age of presentation is 3 to 4 years in the thoroughbreds and 4 to 7 years in draft horse breeds

2. Clinical signs: Exercise intolerance, inspiratory respiratory stridor. Roaring sound; may worsen with neck flexion
3. Diagnosis: Endoscopy
 a. Four grades
 (1) Grade 1: Normal symmetry of both arytenoids during abduction
 (2) Grade 2: Slight flutter or asynchronous movement of one arytenoid; however, full abduction is obtained
 (3) Grade 3: Asynchronous movement of one arytenoid with that arytenoid unable to fully abduct
 (4) Grade 4: Paralysis of one arytenoid with no abduction noted on that side
 b. May need treadmill examination to fully assess grade 2 and 3
4. Treatment: Surgical
 a. Prosthetic laryngoplasty (tie-back): Suture (prosthesis) is placed from cricoid cartilage to muscular process on affected side to mimic atrophied cricoarytenoideus dorsalis muscle (Figure 47-1)
 b. Ventriculocordectomy
 (1) Removal of ventricle (laryngeal saccules) and vocal cord either on affected side or both sides
 (2) Can be performed either through a laryngotomy incision or transendoscopically with a noncontact laser
 (3) May be combined with prosthetic laryngoplasty
 (4) May improve airflow and performance; helps with reduction of abnormal respiratory noise during exercise
 c. Arytenoidectomy
 (1) Performed via laryngotomy incision
 (2) Partial: Removal of everything but muscular process of affected arytenoid cartilage
 (3) Subtotal: Remove everything but muscular process and corniculate process of affected arytenoid cartilage
 (4) Reserved for failed laryngoplasty or infected/damaged arytenoid cartilages
5. Prognosis and complications: With prosthetic laryngoplasty, 50% to 70% return back to performance. Complications from surgical procedures include failure of prosthesis, chronic coughing, and chronic aspiration when eating

C. Arytenoid chondrosis
1. Cause and signalment
 a. Chondropathy associated with infection or damage to arytenoid cartilage (either unilateral or bilateral); results in thickening and malformation of arytenoid cartilage
 b. Thoroughbreds are overrepresented. Horses tend to be older
2. Clinical signs: Respiratory stridor (even at rest), exercise intolerance, dyspnea, cough, dysphagia, acute respiratory distress
3. Diagnosis
 a. Endoscopy: Deformed (thicken, abnormal shape) corniculate process usually nonfunctional or dysfunctional (both affected in severe cases)
 b. Radiology: Mineralization of arytenoids (part or whole) may be seen
4. Treatment
 a. Arytenoidectomy (Figure 47-2)
 (1) Performed via laryngotomy incision
 (2) Partial: Removal of everything but the muscular process of affected arytenoid cartilage
 (3) Subtotal: Removal of everything but the muscular process and corniculate process of affected arytenoid cartilage
 b. May be necessary to have a temporary tracheotomy postoperatively
 c. If both arytenoids are affected severely, may elect to place a permanent tracheostomy
5. Prognosis and complications: Fair to guarded; removal of arytenoid results in inadequate seal

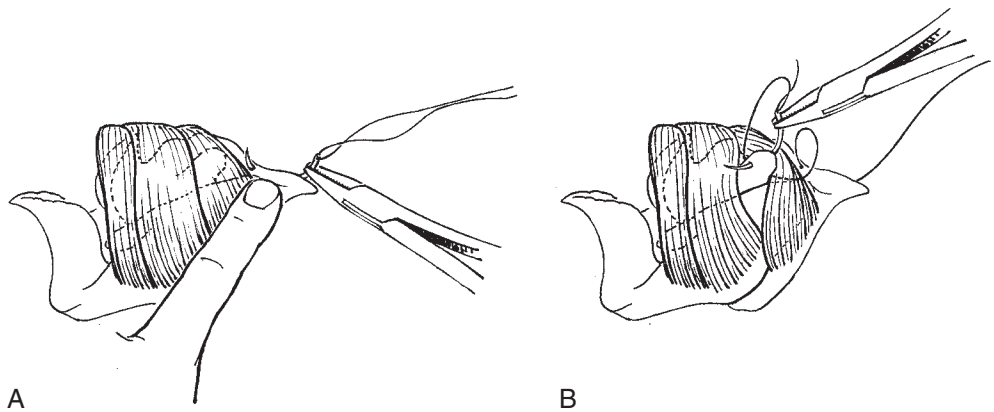


Figure 47-1 Schematic illustration of the laryngoplasty technique. **A,** Placement of the prosthesis in the dorsal, caudal border of the cricoid cartilage. **B,** Placement of the prosthesis in the muscular process of the arytenoid cartilage. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006 Saunders.)

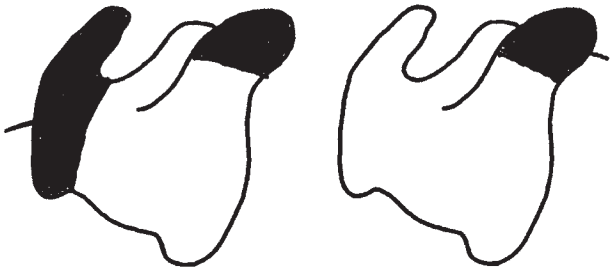


Figure 47-2 Schematic representation of a lateral view of the arytenoid cartilage, demonstrating the portions of the cartilage that are removed (unshaded) during subtotal and partial arytenoidectomy. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006 Saunders.)

during swallowing and increased risk of aspiration. Tracheostomy also could increase the risk of pneumonia

GASTROINTESTINAL TRACT DISORDERS

I. Disorders of the oral cavity
 A. Dental anatomy
 1. Dental formula
 a. Incisors: Six maxillary and six mandibular
 b. Canines: If present (typically in males, variable in females) will have two maxillary and two mandibular in interdental space
 c. Premolars: Up to eight premolars in maxilla and eight on mandible (up to four on each side). The wolf teeth are first premolars, may not be present, and are not included as "cheek teeth"
 d. Molars: Six maxillary and six mandibular (three on each side)
 e. The 2nd, 3rd, and 4th premolars and 1st, 2nd, and 3rd molars also known as cheek teeth
 f. The modified Triadan system for tooth identification is frequently used
 2. Location
 a. All mandibular tooth roots are located within mandible
 b. First two upper cheek teeth (and wolf teeth if present) are within premaxilla and not within a sinus cavity
 c. Last four upper cheek teeth are imbedded in maxilla and roots are located in the cranial and caudal maxillary sinuses
 3. Tooth composition
 a. Enamel: Produced by ameloblast; primary structure of tooth present between dentin and cementum of equine tooth
 b. Cementum: Produced by cementoblast; outer surface of tooth
 c. Dentin: Produced by odontoblast; present within center of tooth and functions as mechanoreceptor for tooth
 d. Pulp: Most central aspect of tooth; composed of blood vessels, lymphatics, connective tissue and nerves
 B. Brachygnathia (parrot mouth)
 1. Cause and signalment
 a. Congenital malformation where the mandible is shorter than maxilla
 b. Any breed or age but is present at birth; may be heritable
 2. Clinical signs: Presence of overbite, difficulty grazing
 3. Diagnosis: Physical examination
 4. Treatment: Management depending on severity; might not be able to graze
 C. Wry nose
 1. Cause and signalment: Congenital malformation with severe facial malformation and incisor malocclusion. Condition involves nasal, vomer, incisive, premaxillary, and maxillary bones; very rare
 2. Clinical signs: Severe malformation, obvious at birth
 3. Diagnosis: Physical examination; radiology used to determine extent of bone involvement
 4. Treatment: Management varies depending on severity. If greater than 20 degrees of deviation, then surgical correction in necessary
 5. Prognosis and complication: Usually poor; complications related to problems eating and breathing (especially due to deviation of nasal bones)
 D. Wolf teeth
 1. Cause and signalment
 a. Wolf teeth (PM1 or 105, 205, 305, and 405): Normal teeth; may or may not be present. Typically upper teeth present, but not lower ones
 b. Typically erupt at 5 to 6 months of age
 c. Must not confuse with canines
 2. Clinical signs: History of head shaking, particularly when wearing a bit
 3. Diagnosis: Oral examination. Radiology: If the tooth has not fully erupted or if previously broken off, the remaining root may be seen radiographically
 4. Treatment: Owners often elect for removal; wolf tooth extraction
 5. Prognosis and complication: Good. Complications secondary to extraction: Laceration of palatine artery (sets medial to tooth in the hard palate), fracture of tooth resulting in incomplete removal. Not a problem if tooth fractures above gingival lining
 E. Retained deciduous teeth and crowns
 1. Cause and signalment
 a. Also known as "caps." Premolars only
 b. Occur between 2 and 5 years of age
 c. These retained crowns allow feed to accumulate around tooth and impaction of permanent tooth, which can result in severe inflammation, infection, or dental arcade deformities in severe cases
 2. Clinical signs: Mild dysphagia
 3. Diagnosis: Oral examination; radiology. Allows for evaluation of permanent tooth alignment

and assessment of roots for associated periapical infections
4. Treatment
 a. Conservative: Antiinflammatories, antibiotics, time
 b. Removal of retained deciduous crowns if permanent tooth has erupted at gingiva
5. Prognosis and Complications: Fair to good; if no deformities or periapical infections. Complications: Periodontal infection if retained crown is removed before the permanent tooth has completely erupted

F. Periapical infections
1. Cause and signalment
 a. Tooth root infections that typically occur as extension of sepsis from periodontal tissues; infection results not from the center (pulp), but instead from the periodontal structures surrounding the tooth. Infections will invade pulp cavity of tooth and eventually destroy tooth and surrounding bone and tissues
 b. Occur in any breed but typically in horses 5 years old or older
2. Clinical signs
 a. Halitosis
 b. Weight loss
 c. Difficulties eating or quidding
 d. Nasal discharge: If the 3rd through 6th maxillary cheek teeth (108-111 or 208-211) are involved as roots communicate with maxillary sinuses
 e. Swelling or draining tract over affected tooth root if mandibular (306-311 or 406-411) or 1st two maxillary (106, 107, 206, 207) cheek teeth are involved
3. Diagnosis
 a. Oral examination: Affected teeth may be loose, have feed packed around affected tooth, and have proliferative gingiva that forms a pocket surrounding the tooth
 b. Radiology
 (1) Views: DV, lateral, right, and left oblique lateral (taken 35 to 45 degrees from true lateral), and intraoral. The most diagnostic view is oblique lateral with diseased side closest to film
 (2) Radiographic findings: Bone lysis, widening of periodontal space, loss of alveolar bone margins, blunting or irregularities to tooth root, fluid in sinus if last four maxillary cheek teeth are involved
 (3) If a draining tract is present, contrast study or placement of a metal probe could help to identify the affected tooth.
 c. Nuclear scintigraphy
 (1) Can be used to find areas of increased bone metabolism
 (2) Radiolabeled white blood cells (WBCs) to find focal areas of infection. Still need other imaging modality to identify the exact tooth
 d. CT and magnetic resonance imaging (MRI): Provide more detail; perfect if infection is in the early process or there is minimal radiographic abnormalities. Very useful in determining specific tooth involvement
4. Treatment
 a. Conservative: Medical with antiinflammatories, antibiotics. Often not curative; helps with halitosis and nasal discharge
 b. Periapical curettage
 (1) Treatment of choice if pulp cavity is not involved and periodontal ligament is still intact
 (2) Used to treat PM2; PM3 of maxilla; and PM2, PM3, PM4, M1, and M2 of mandible. M3 is too difficult to drain because the masseter muscle and PM4-M3 of maxilla are in sinus cavity and surgical access is limited
 (3) Apex is accessed surgically, usually via a trephine hole over the root and after curettage the defect is left open for drainage
 c. Endodontic therapy
 (1) Careful case selection; used in adults with well-developed roots system with diseased pulp. Must have intact periodontal ligament
 (2) Approach from apical portion of the tooth; remove all diseased pulp with reamers, sterilize pulp cavity with 5% sodium hypochlorite, dry pulp cavity, and retrograde fill with dental amalgam
 d. Cheek tooth repulsion
 (1) Typically requires general anesthesia; however, standing repulsion of teeth located in the maxillary sinus possible
 (2) Surgical approach varies, depending on tooth involved
 (a) Mandibular premolars and molars: Lateral approach through mandibular alveolar plate
 (b) Maxillary PM2 and PM3: Lateral buccotomy
 (c) Maxillary PM4: Rostral maxillary sinus flap
 (d) Maxillary molars: Caudal maxillary sinus flap
 (3) Radiographic guidance is important to make sure that the correct tooth is being repulsed
 (4) After repulsion, the socket is dried and packed for 4 to 6 weeks
 e. Oral extraction: Done either standing or under general anesthesia; ideal if tooth is loose
5. Prognosis and complication
 a. Fair to good overall. Periapical curettage and endodontic therapy may require tooth to be removed at a later date if infection was not removed
 b. Complications include iatrogenic damage (adjacent teeth, mandible, or maxilla),

incomplete extraction, inadvertent damage to soft tissue, oral-nasal fistula formation, infection of adjacent tooth, bone sequestration, chronic sinusitis, draining tracts, retained dental packing, feed impaction of alveolus or sinus
c. Complication rates: Maxillary teeth = 47%, mandibular teeth = 32%

II. Disorders of the esophagus
A. Esophageal anatomy
1. Tunica adventitia: Outer layer
a. Thin fibrous layer so has poor holding power; thus surgery in this area will typically result in leakage of esophageal contents
b. Serosa is present surrounding the abdominal portion of the esophagus
2. Tunica muscularis: Cranial two thirds = striated muscle; caudal one third = smooth muscle
3. Tela submucosa
4. Tunica mucosa: Inner layer
a. In longitudinal folds that stretch during swallowing
b. Strongest layer: Holding layer for sutures if surgery is necessary
B. Esophageal obstruction
1. Cause and signalment: Any age, breed, or sex; rule out neurologic cause for obstruction. Obstruction can consist of hay, grass, pellets, grain, shavings, or foreign body (e.g., twine, apple, twigs, wire)
2. Clinical signs include ptyalism, dysphagia, dehydration, painful swallowing, coughing, nasal discharge (typically food and water)
3. Diagnosis
a. Clinical findings: Unable to pass nasogastric (NG) tube into the stomach. Palpate neck; feel for crepitus or cellulitis suggestive of esophageal rupture. Auscultate the thorax
b. Endoscopy: Cannot determine length of obstruction but may help to identify location and cause. Allows for assessment of mucosa and determine whether any esophageal defects are present
c. Radiology: Cervical and thorax films to assess obstruction and pneumonia; plain films followed by contrast (barium)
d. Ultrasound: Thoracic ultrasound may help to determine presence and severity of aspiration pneumonia
4. Treatment
a. Esophageal lavage
(1) Uses a large-bore or double-bore NG tube and gentle lavage with water
(2) Sedation (typically with xylazine or detomidine) is essential; makes it easier to lavage and keeps horse's head down to decrease chance of aspiration
(3) Other agents to relax the esophagus and decrease spasm of esophagus (intravenous [IV] oxytocin, lidocaine via NG tube or endoscope)
(4) More aggressive lavage can be performed with patient under general anesthesia, which could help decrease the risk of aspiration
b. Endoscopic removal combined with lavage. Difficult to remove most obstruction with endoscopic equipment
c. Esophagotomy
(1) Can be done standing, but general anesthesia preferred
(2) Either suture closed or leave open to heal by second intention
(3) No feed or water for 48 to 72 hours postoperatively
5. Prognosis and complications
a. Prognosis = good to fair
b. Complications: Aspiration pneumonia, acid-base or electrolyte abnormalities, dehydration, esophageal stricture or rupture, esophageal diverticulum, dehiscence at esophagotomy site, laryngeal hemiplegia
C. Esophageal stricture
1. Etiology and signalment
a. Secondary to trauma, laceration, esophageal surgery, or obstruction. Lumen diameter will be the smallest at 30 days. Need to wait 60 days post trauma before surgical intervention. Affects any age, breed, or sex
b. Three types
(1) Mural: Involves adventitia and muscularis
(2) Annular: Involves all layers
(3) Webs: Involves mucosa and submucosa
2. Clinical signs: Signs of esophageal obstruction if obstructed at presentation
3. Diagnosis: History of esophageal obstruction or trauma; endoscopy, radiology (plain films followed by barium contrast)
4. Treatment
a. Conservative: Antiinflammatories, antibiotics, soft feed. May be able to manage without surgery
b. Serial bougienage: Not very effective and difficult to find equipment
c. Esophagomyotomy: Used for mural strictures under general anesthesia; incisions made into muscular layer until it separates from mucosa. This layer is not sutured closed. This should release the stricture; can recur with healing
d. Resection and anastomosis: General anesthesia; need to train to a martingale to help minimize tension and allow for healing
5. Prognosis and complications
a. Prognosis: Fair to guarded depending on treatment. If medically managed then prognosis fair
b. Complications: Recurrence of stricture; failure of resection, and anastomosis
D. Esophageal diverticulum
1. Cause and signalment: Not common. Two types occur:
a. Traction: After trauma or surgery; does not cause a problem. All layers pulled down to

form a shallow, long diverticulum that has no neck
b. Pulsion: Mucosa herniates through tear in muscularis; narrow neck forms resulting in frequent impactions
2. Clinical signs: History of esophageal obstructions
3. Diagnosis: Endoscopy, radiology (plain films followed by barium contrast)
4. Treatment
a. Conservative: Soft feed is typically successful for traction diverticulum
b. Surgery: Invert mucosa and repair defect in muscularis
5. Prognosis and complications
a. Prognosis: Good if traction; fair to guarded if pulsion
b. Complications: Chronically recurring esophageal obstruction; esophageal rupture

III. Disorders of the small intestine
A. Overview
1. Approximately 85 to 90 feet of small intestine are present in the horse
2. Most small intestinal disorders are acute and result in abdominal pain (colic)
3. Obstructions are common
a. Functional: Ileus. Secondary to inflammation, postoperative
b. Physical: Nonstrangulating or strangulating
B. Duodenitis-proximal enteritis
1. Cause and signalment: Any breed, age, or sex; secondary to *Salmonella* or *Clostridium*; results from a functional ileus
2. Clinical signs: Fever, tachycardia (high on presentation, decreases with gastric decompression), injected or toxic mucous membranes, prolonged capillary refill time, dehydration, decreased gastrointestinal (GI) sounds, colic
3. Diagnosis
a. NG intubation: Typically yields large amount of net reflux; reflux may be sour smelling or hemorrhagic
b. Rectal palpation: Mild to moderate small intestinal distention
c. Transabdominal ultrasound
(1) Multiple loops of mild to moderate distended small intestine
(2) Intestinal wall may be thicken (>4 mm) and appear corrugated
d. CBC
(1) WBC: Either leukocytosis or leucopenia
(2) Packed cell volume (PCV), temperature, and pressure (TP): Typically increased secondary to dehydration
(3) Fibrinogen: May be increased
e. Chemistry
(1) Increased protein concentration
(2) Increased creatinine and blood urea nitrogen (BUN) concentration
(3) Increase anion gap: Secondary to lactic acidosis
(4) May have decreased chloride concentration
(5) May have increased liver enzymes
f. Abdominocentesis
(1) Protein concentration is typically elevated (often over 4 g/dL)
(2) Nucleated cell count is usually normal to slightly elevated (less than10,000 cells/μL)
4. Treatment (medical)
a. Frequent (every 2 to 4 hours) gastric decompression
b. IV balanced electrolyte fluids
c. Antiendotoxic therapies
(1) Endoserum: Serum from horse immunized against endotoxin (LPS)
(2) Polymixin B (2000 units/kg to 5000 units/kg). Binds to lipid poly A portion of the LPS
d. Antibiotics (broad spectrum) if significant leucopenia is present
e. Antiinflammatories: Flunixin meglumine at 1.1 mg/kg every 24 h to every 12 h
5. Prognosis and complications: Prognosis fair to guarded. Complications include laminitis, renal failure, diarrhea/colitis, cholangiohepatitis, disseminated intravascular coagulopathy (DIC)
C. Ascarid impaction
1. Causes and signalment: Any sex or breed; typically weanlings or yearlings
2. Clinical signs: Mild fever (secondary to parasitic inflammation), tachycardia, injected or toxic mucous membranes, dehydration, decreased GI sounds
3. Diagnosis
a. NG intubation: Depending on site of obstruction and duration of colic, net reflux obtained. Ascarid worms may be present in gastric fluid
b. Rectal palpation: Small intestinal distention present
c. Transabdominal ultrasound
(1) Multiple loops of mild to moderate distended small intestine
(2) Hyperechoic structures in lumen of small intestine may be consistent with parasites
d. CBC: WBC variable findings; PCV/TP: Typically increased secondary to dehydration
e. Chemistry
(1) Increased protein concentration
(2) Increased creatinine and BUN concentration if dehydrated
(3) Increase anion gap: Secondary to lactic acidosis
(4) Decreased chloride concentration secondary to gastric reflux
f. Abdominocentesis
(1) Protein concentration mildly elevated (greater than 2.5 to 3.0 g/dL)
(2) Nucleated cell count normal to slightly elevated (less than 10,000 cells/μL)

4. Treatment
 a. Treat medically if pain can be managed.
 (1) Frequent (every 2 to 4 hours) gastric decompression
 (2) IV balanced electrolyte fluids
 (3) Pain management: Flunixin meglumine, xylazine, detomidine, butorphanol
 b. Surgery if signs persist. Enterotomy to remove impaction and ascarids
5. Prognosis and complication
 a. Fair to guarded, depending on treatment
 b. Complications: Enteritis, diarrhea-colitis. Surgical complications: Adhesions, incisional infection, peritonitis

D. Intussusception
1. Causes and signalment
 a. Any sex or breed; more frequent in younger horses
 b. Types
 (1) Jejunal-jejunal: Generally occur in younger horses
 (2) Jejunal-ileal
 (3) Ileal-cecal. Tapeworm infection may predispose
 c. Occurs secondary to alterations in motility; result of intestinal inflammation (from other disorders such as enteritis or parasites)
 d. Two parts
 (1) Intussusceptum: Portion that has telescoped in
 (2) Intussuscipiens: Portion that receives the telescoped intestine
2. Clinical signs
 a. Colic (may be intermittent; moderate to severe if not self-reducible), tachycardia, dehydration, decreased GI sounds
3. Diagnosis
 a. NG intubation: Depending on site of obstruction and duration of colic, net reflux may be obtained
 b. Rectal palpation: Small intestinal distention may be present
 c. Transabdominal ultrasound
 (1) Multiple loops of mild to moderate distended small intestine
 (2) May find "target" lesion which is a cross-sectional loop of small intestine inside another cross-sectional loop of small intestine
 d. CBC: WBC variable, but typically normal; PCV/TP increased secondary to dehydration
 e. Chemistry: Increased creatinine and BUN concentration if dehydrated
 f. Abdominocentesis: Protein concentration and nucleated cell count. Typically results are within normal limits even if bowel is compromised as the dead bowel is contained within itself
4. Treatment
 a. May self-reduce; risk that intestines will be compromised. Frequent (every 2 to 4 hours) gastric decompression; IV balanced electrolyte fluids; pain management (flunixin meglumine, xylazine, detomidine, butorphanol)
 b. Surgical treatment recommended. Reduction of the intussusception (if possible); resection and anastomosis if bowel is compromised or if the intussusception cannot be reduced
5. Prognosis and complication
 a. Fair to guarded, depending on treatment. Typically better for jejunal-jejunal intussusception than for ileal-cecal intussusceptions
 b. Complications: Recurrence of intussusception, diarrhea, surgical complications (adhesions, incisional infection, peritonitis)

E. Volvulus
1. Cause and signalment
 a. Any sex, age, or breed
 b. Torsion of the small intestine along the mesenteric axis
 c. Can vary in length and amount of small intestine involved
 (1) Root of mesentery volvulus: Involves the entire small intestine
 (2) Segmental: Only a portion involved
2. Clinical signs: Colic (severe, acute onset), tachycardia, injected or toxic or pale mucous membranes, prolonged capillary refill time (CRT), decreased or absent GI sounds, dehydration
3. Diagnosis
 a. NG intubation: Depending on the site of obstruction, some net reflux may be obtained
 b. Rectal palpation: Multiple loops of distended small intestine present
 c. Transabdominal ultrasound: Multiple loops of moderate to severe distended loops small intestine
 d. CBC: WBC normal; PCV, TP increased secondary to dehydration
 e. Chemistry: Increased creatinine and BUN (if dehydrated); increased anion gap secondary to lactic acidosis
 f. Abdominocentesis: Protein concentration and nucleated cell count (NCC): Depending on duration, but typically both are increased significantly (protein greater than 3 g/dL; NCC greater than 10,000)
4. Treatment: Surgical correction of volvulus, decompression of gas and fluids; resection and anastomosis if segmental and bowel viability is questionable
5. Prognosis and complication
 a. Prognosis: Guarded
 b. Complications: Postoperative ileus, adhesions, dehiscence, or stricture at anastomotic site, peritonitis, incisional infections, diarrhea, endotoxemia, laminitis

F. Epiploic foramen entrapment
1. Cause and signalment
 a. Any sex or breed; any age; middle-aged horses overrepresented

b. Small intestine becomes entrapped in epiploic space (between right caudate lobe of liver, portal vein, and caudal vena cava)
c. Increase incidence in horses that are cribbers (Figure 47-3)

2. Clinical signs: Severe, acute colic, tachycardia, injected, toxic, or pale mucous membranes, prolonged CRT, decreased or absent GI sounds, dehydration
3. Diagnosis
 a. NG intubation: Net reflux is usually obtained
 b. Rectal palpation: Multiple loops of distended small intestine
 c. Transabdominal ultrasound
 (1) Multiple loops of moderate to severe (5- to 8-cm diameter) distended loops of small intestine that are nonmotile
 (2) Thickened (i.e., greater than 4 mm) small intestinal walls
 d. CBC: WBC variable; PCV, TP increased secondary to dehydration
 e. Chemistry: Increased creatinine and BUN if dehydrated; increased anion gap secondary to lactic acidosis
 f. Abdominocentesis: Protein concentration and nucleated cell count; depending on duration, but typically both are increased significantly (protein greater than 3 g/dL; NCC greater than 10,000)
4. Treatment: Surgery. Correct entrapment, decompression of gas and fluids. Resection and anastomosis if bowel viability is questionable
5. Prognosis and complication
 a. Prognosis is guarded
 b. Complications: Postoperative ileus, adhesions, dehiscence, or stricture at anastomotic site, peritonitis, incisional infections, diarrhea, endotoxemia, laminitis, hemorrhage (portal vein rupture during surgery, mesenteric vessels after resection)

G. Pedunculated lipomas
1. Cause and signalment
 a. Any sex or breed; older horses.
 b. Lipomas form from mesentery fat; as they become larger and heavier, loops of small intestine become twisted around stalk, which results in luminal obstruction as well as compromised blood supply to the intestine
2. Clinical signs: Severe colic, tachycardia, injected, toxic, or pale mucous membranes; prolonged CRT; decreased or absent GI sounds, dehydration
3. Diagnosis
 a. NG intubation: Net reflux is may obtained depending on site of obstruction and duration of colic
 b. Rectal palpation: Multiple loops of distended small intestine
 c. Transabdominal ultrasound
 (1) Multiple loops of moderate to severe (5- to 8-cm diameter) distended loops of small intestine that are nonmotile
 (2) Thickened (greater than 4 mm) small intestinal walls may be seen
 d. CBC: WBC variable; PCV, TP increased secondary to dehydration

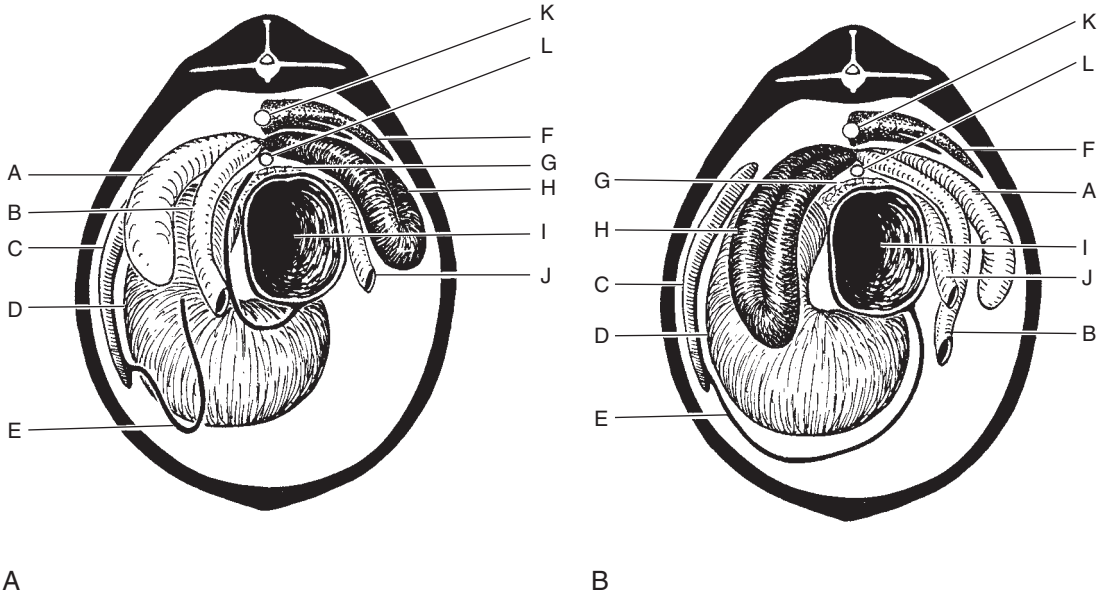


Figure 47-3 Epiploic foramen strangulation. Left to right **(A)** and right to left **(B)** herniation of the small intestine through the epiploic foramen. *a,* jejunum proximal to strangulation; *b,* jejunum distal to strangulation; *c,* spleen; *d,* stomach; *e,* greater omentum, torn during strangulation; *f,* liver; *g,* pancreas; *h,* strangulated loop; *i,* right dorsal colon; *j,* duodenum; *k,* vena cava; *l,* portal vein. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

e. Chemistry: Increased creatinine and BUN if dehydrated; increased anion gap secondary to lactic acidosis
f. Abdominocentesis: Protein concentration and NCC is variable depending on duration, but typically both are increased significantly (protein greater than 3 g/dL; NCC greater than 10,000)

4. Treatment: Surgery to correct and remove lipoma, decompression of gas and fluids, resection if bowel viability is questionable
5. Prognosis and complication
 a. Prognosis is guarded
 b. Complications: Postoperative ileus, adhesions, dehiscence, or stricture at anastomotic site, peritonitis, incisional infections, diarrhea, endotoxemia, laminitis

H. Inguinal hernias
1. Cause and signalment
 a. Stallions; very rarely gelding or mare
 b. Any age: In adults, inguinal hernias are acquired and nonreducible; foals typically have congenital hernias that are reducible
 c. Breeds: More common in standardbreds and Tennessee walking horses because of their larger inguinal rings
 d. Types
 (1) Indirect: Most common; occurs when small intestine passes through vaginal ring into vaginal tunic
 (2) Direct: Not common; however, more common in foals (up to 48 hours old); occurs when a rent is present in peritoneum allowing small intestine and occasionally testicle to lay outside the vaginal tunic in subcutaneous space
2. Clinical signs
 a. Colic: Pain is variable, typically painful initially, and then pain returns 3 to 4 hours later as small intestinal distention occurs
 b. Scrotal area may be swollen, firm, painful, and cool to the touch on the affected side
 c. Other signs include tachycardia, decreased or absent GI sounds, dehydration, injected/toxic mucous membranes
3. Diagnosis
 a. NG intubation: Net reflux may be obtained depending on site of obstruction and duration of colic
 b. Rectal palpation: Small intestinal loop within the inguinal ring; multiple loops of distended small intestine
 c. Transabdominal ultrasound: Multiple loops of moderate to severe (5- to 8-cm diameter) distended loops of no-motile small intestine; thickened (>4 mm) walls, particularly in scrotal sac if intestine is compromised
 d. CBC: WBC variable depending on duration; PCV, TP increased secondary to dehydration
 e. Chemistry: Increased creatinine and BUN if dehydrated
 f. Abdominocentesis: Protein concentration and nucleated cell count typically within normal limits as intestine is entrapped in an enclosed space and changes in the abdominal fluid are not noted until later
4. Treatment
 a. Reducible indirect: Congenital; reduce externally; follow with laparoscopic inguinal herniorrhaphy or castration with closure of inguinal ring
 b. Nonreducible indirect: Exploratory celiotomy followed by castration and closure of inguinal ring; resect if bowel viability is questionable
 c. Direct: Requires surgery to repair torn edges of vaginal tunic and reduce hernia; not necessary to resect affected portion; exploratory celiotomy indicated if necessary
5. Prognosis and complication
 a. Prognosis: Fair to good; 76% survival rate. Poor to guarded for breeding
 b. Complications: Adhesions, postoperative ileus, incisional infections, endotoxemia; if not castrated, the testicle can become cystic or nonfunctional; nonaffected testicle can be degenerative secondary to swelling and trauma of affected side

I. Ileal impaction, ileal hypertrophy
1. Cause and signalment
 a. Any sex or breed; middle-aged to older horses
 b. Occurrence associated with coastal hay feeding (small fine fibers can impact in this area) or tapeworm infection (at the ileocecal junction). Coastal hay–associated ileal impactions are typically seen in the South (i.e., North and South Carolina, Georgia, Florida, Alabama, Louisiana, Mississippi)
2. Clinical signs: Moderate colic, frequent colic with hypertrophy; tachycardia, decreased or absent GI sounds, dehydration (mild to moderate)
3. Diagnosis
 a. NG intubation: Net reflux may or may not be obtained
 b. Rectal palpation: Multiple loops of distended small intestine; thickened, impacted loop of small intestine (ileum) palpated just axial to cecum
 c. Transabdominal ultrasound: Multiple loops of moderate to severe (5- to 8-cm diameter) distended loops of small intestine that are nonmotile
 d. CBC: WBC variable; PCV, TP increased secondary to dehydration
 e. Chemistry: Increased creatinine and BUN with dehydration
 f. Abdominocentesis: Protein and nucleated cell count normal
4. Treatment
 a. Medical: Pain management (xylazine, detomidine, butorphanol, flunixin meglumine), IV fluid therapy, correct electrolyte abnormalities; gastric decompression as necessary

b. Surgical: External manipulation of impacted ileum and decompression into cecum; in severe cases perform enterotomy. Perform jejunocecostomy if recurring colic

5. Prognosis and complications
 a. Prognosis: Fair to good
 b. Complications: Reimpaction, enteritis, diarrhea, endotoxemia; surgery-associated include postoperative ileus, adhesions, incisional infection

J. Adhesions
1. Cause and signalment
 a. Typically from prior abdominal surgery; however, castration or peritonitis (i.e., abdominal abscess) can lead to adhesions. Surgical procedure most likely occurred within 6 to 12 months of colic episode
 b. Occur secondary to excessive damage of mesothelial lining with intestinal inflammation or ischemia; depresses fibrinolytic activity, resulting in persistence of intra-abdominal fibrin and adhesion formation
 c. Risk factors for adhesions from surgery: Distention, contamination, handling of intestine, allowing serosal surface of intestine to dry out, inflammation, ischemia
2. Clinical signs
 a. Colic (may be chronic with acute presentation; varies depending on obstruction or strangulation), tachycardia, decreased/absent GI sounds
3. Diagnosis
 a. NG intubation: Net reflux obtained
 b. Rectal palpation: Multiple loops of distended small intestine
 c. Transabdominal ultrasound: Multiple loops of mild to moderately distended nonmotile small intestine
 d. Abdominocentesis: Protein and nucleated cell count normal unless there is strangulated, compromised intestine
4. Treatment
 a. Surgery: Break down adhesions manually via celiotomy or laparoscope
 b. Medical: If adhesions are not causing an obstruction, attempts to treat medically by controlling pain and decreasing bulk of fiber in diet to decrease weight of intestine and pull of adhesions may be successful
5. Prevention: 1% sodium carboxymethylcellulose (CMC), which is a lubrication barrier placed intraperitoneally; hyaluronate-carboxymethylcellulose (HA-CMC) membrane; adherence to Halsted's surgical principles, including minimal, atraumatic tissue handling, adequate hemostasis, short surgical time, prevention of contamination of surgical site, prevention of exposure to foreign materials; heparin typically at 40 to 80 units/kg IV, intramuscularly (IM), or subcutaneously (SC); omentectomy; decreased incidence of postoperative ileus; antibiotics, antiinflammatories; abdominal lavage
6. Prognosis and complications: Prognosis is guarded. Complications include reformation of adhesions and complications associated with surgery

IV. Disorders of the cecum
A. Anatomy of the cecum: Cecum is a blind-ended saclike structure comprising three parts: The apex, body, and base. Four teniae (bands) are present on cecum: Dorsal (ileocecal band), ventral, lateral (cecocolic band), and medial (Figure 47-4)
B. Cecal impactions
1. Cause and signalment: Any sex or breed; increased in painful (orthopedic or ophthalmic) hospitalized patients. Two types:
 a. Type I: Feed- or ingesta-filled cecal contents. Poor dentition and infection with

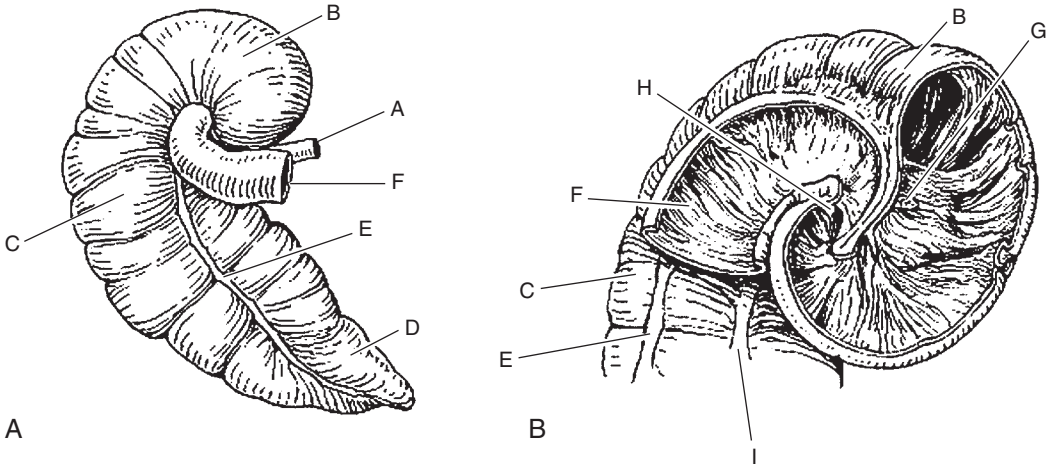


Figure 47-4 **A,** Cecum of the horse, right lateral aspect. **B,** Base of the cecum and the proximal part of the ascending colon (right ventral colon) of the horse, opened laterally to show the ileal and cecocolic orifices. Fixed in situ. Lateral aspect. *a,* ileum, elevated; *b,* base of cecum; *c,* body of cecum; *d,* apex of cecum; *e,* lateral teniae; *f,* proximal part of right ventral colon; *g,* ileal orifice on papilla; *h,* cecocolic orifice; *i,* dorsal teniae with ileocecal fold. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006 Saunders.)

Anoplocephala perfoliata (tapeworms) may be predisposing factors
 b. Type II: Fluid-filled cecal contents. Signs more severe; not as common
2. Clinical signs: Colic (mild until severe distention occurs); decreased feed intake and fecal output, decreased or absent GI sounds (particularly right side), dehydration (mild to moderate)
3. Diagnosis
 a. NG intubation. Net reflux is typically not obtained
 b. Rectal palpation: Tautness of ventral cecal band; with progression, firm ingesta- or gas-filled structure will be palpated on the right side
 c. Transabdominal ultrasound normal unless cecum is filled with fluid
 d. CBC: WBC normal; PCV, TP mild increase secondary to dehydration
 e. Chemistry: Increased creatinine and BUN secondary to dehydration
 f. Abdominocentesis: Protein and nucleated cell count normal
4. Treatment
 a. Medical: Pain management (xylazine, detomidine, butorphanol, flunixin meglumine); IV fluid therapy; enteral fluids; laxatives (mineral oil, magnesium sulfate [Epson salt]), psyllium, dioctyl sodium sulphosuccinate (DSS); no feed or hay until impaction passes
 b. Surgical: Typhlotomy (incision into the cecum to evacuate the contents); cecal bypass (ileocolic or jejunocolic anastomosis) if cecal dysmotility is suspected (recurrence or type II)
5. Prognosis and complications
 a. Prognosis is fair to good
 b. Complications: Rupture of cecum, recurrence, endotoxemia, diarrhea, adhesions or incisional infection after surgery

C. Cecal tympany
1. Cause and signalment
 a. Any sex or breed
 b. Secondary to increased consumption of carbohydrates (such as lush pasture grass or high grain diet), particularly if not part of routine diet
2. Clinical signs: Moderate colic; severe if distention worsens; increased GI sounds (classic ping on right upper abdominal quadrant). If severe, gross abdominal distension may be present
3. Diagnosis
 a. NG intubation: No net reflux
 b. Rectal palpation: Mild to moderate tension of the ventral cecal band
 c. Transabdominal ultrasound is unremarkable
 d. CBC, chemistry: Normal. Abdominocentesis: Not indicated; protein and nucleated cell count normal
4. Treatment: Medical
 a. Pain management (xylazine, detomidine, butorphanol, flunixin meglumine)
 b. Buscopan (*N*-butylscopolammonium bromide): Antispasmodic and anticholinergic drug
 c. IV fluids if dehydrated, correct electrolyte abnormalities
 d. Cecal trocharization in severe cases only; can result in tearing of cecal wall and peritonitis
5. Prognosis is good

D. Cecal intussusception
1. Cause and signalment
 a. Any sex, breed, or age. *Anoplocephala perfoliata* (tapeworm) infestation plays a role in development
 b. Two types involving the cecum: Ileocecal or cecocolic
 c. Acute or chronic: Acute is reducible with surgery; chronic not reducible and requires resection
2. Clinical signs: Chronic mild colic; severe if acute; tachycardia, decreased GI sounds
3. Diagnosis
 a. NG intubation depends on type and duration. With ileocecal intussusception may have net reflux
 b. Rectal palpation is variable depending on type
 (1) Ileocecal: Small intestinal distension with "mass" in the right dorsal aspect of abdomen
 (2) Cecocolic: Inability to palpate cecum may be noted
 c. Transabdominal ultrasound: May find target lesion (lumen within a lumen) on the right side of the abdomen
 d. CBC: WBC variable, may increase if chronic; PCV, TP increased with dehydration
 e. Chemistry: Increased creatinine and BUN secondary to dehydration
 f. Abdominocentesis: Protein concentration and nucleated cell count are variable; normal if affected bowel is telescoped within normal bowel. Chronic cases have increased protein
4. Treatment: Surgery. Resection not needed if reducible with viable intestine; resection and anastomosis if not reducible or intestine is not viable
5. Prognosis and complications
 a. Prognosis is guarded to fair
 b. Complications: Postoperative ileus, adhesions, dehiscence at anastomotic site, peritonitis, endotoxemia, incisional infection, diarrhea, laminitis, recurrence

V. Disorders of the large colon

A. Overview
1. Primary source of water absorption; can have rapid and large volumes of fluid shifts either into the lumen or out of the colon into the vasculature

2. Anatomy of the large colon (from oral to aboral)
 a. Right ventral colon
 b. Sternal flexure: Right to left
 c. Left ventral colon
 d. Pelvic flexure: Left side, ventral to dorsal. Site of impaction due to luminal narrowing
 e. Left dorsal colon
 f. Diaphragmatic flexure: Left to right
 g. Right dorsal colon is a common site for ulcer development secondary to nonsteroidal antiinflammatory drugs (NSAIDs) use
 h. Transverse colon
3. Disorders of large colon can be classified into five groups:
 a. Inflammatory: Colitis (see equine medicine section for details)
 b. Tympany
 c. Simple nonstrangulating obstructions
 (1) Impactions (sand, feed)
 (2) Colon displacements
 (3) Enterolithiasis
 d. Strangulating obstructions
 e. Nonstrangulating infarction

B. Large colon impaction
1. Cause and signalment
 a. Any sex, breed, or age
 b. Predisposing factors include poor dentition, poor forage quality, lack of water source, or poor water consumption. Sand impaction associated with environment (i.e., sandy soil in pasture or in stall)
 c. Types of impaction
 (1) Feed
 (2) Sand: Accumulates quickly and completely obstructs right dorsal and transverse colon. Moderate to severe colic with significant gas distension cranial to impaction. May accumulate more slowly in ventral colon. Mild to moderate colic; history of intermittent chronic colic. Diarrhea, poor hair coat, weight loss
2. Clinical signs: Mild to moderate colic, decreased or absent GI sounds, mild tachycardia, mild to moderate dehydration
3. Diagnosis
 a. NG intubation: Net reflux is typically not obtained
 b. Rectal palpation: Feed typically impacts in right dorsal (not palpable) and in pelvic flexure (palpable); gas distention of large intestine present if impaction is obstructing flow of gas
 c. Transabdominal ultrasound is usually unremarkable
 d. CBC: WBC normal; PCV, TP mild to moderate increase secondary to dehydration
 e. Chemistry: Increased creatinine and BUN secondary to dehydration; increased GGT (γ-glutamyltransferase) from cholestasis secondary to large intestinal (primarily right dorsal colon) compression of biliary outflow; increased bilirubin (indirect) secondary to anorexia
 f. Abdominocentesis: Protein concentration and nucleated cell count normal unless increased duration and inflammation present secondary to impaction; mild increased protein or cell count more common with sand impactions
4. Treatment
 a. Medical: Usually can resolve with medical treatment
 (1) Pain management (xylazine, detomidine, butorphanol, flunixin meglumine)
 (2) IV fluid therapy to correct dehydration
 (3) Enteral fluids
 (4) Laxatives (mineral oil, magnesium sulfate (Epson salt), psyllium (treatment of choice for sand impactions), dioctyl sodium sulphosuccinate (DSS)
 (5) No feed or hay until impaction passes
 b. Surgical: Pelvic flexure enterotomy to evacuate contents
5. Prognosis and complications
 a. Prognosis is good. Slightly worse with sand impactions
 b. Complications: Rupture of large colon, focal necrosis secondary to pressure necrosis of impaction, endotoxemia, diarrhea; surgery associated include adhesions, incisional infection, leakage from enterotomy, peritonitis

C. Large colon displacement
1. Cause and signalment
 a. Any sex, breed, or age
 b. Predisposing factors unknown. Larger frame horses (thoroughbred, draft horses) at increased risk due to increased size of large intestine, more abdominal space, and increased size of nephrosplenic space
 c. Cause unknown; Changes in motility suspected and could be secondary to parasites or changes in feed type or water intake
 d. Two types:
 (1) Right dorsal displacement: Large colon moves from its normal location to set on right side between body wall and cecum (Figure 47-5)
 (2) Left dorsal displacement (nephrosplenic entrapment): Left ventral and dorsal colon entrapment on ligament between dorsal spleen and left kidney (Figure 47-6)
2. Clinical signs: Moderate to severe colic, pain secondary to gas distention, decreased or absent GI sounds, heart rate normal to slightly increased, mild dehydration, gross abdominal distention
3. Diagnosis
 a. NG intubation: Net reflux is typically not obtained
 b. Rectal palpation is variable depending on type of displacement
 (1) Right dorsal displacement: Gas distension of the large colon; criss-crossing taut colonic bands palpated (right dorsal to left ventral and left dorsal to right ventral)

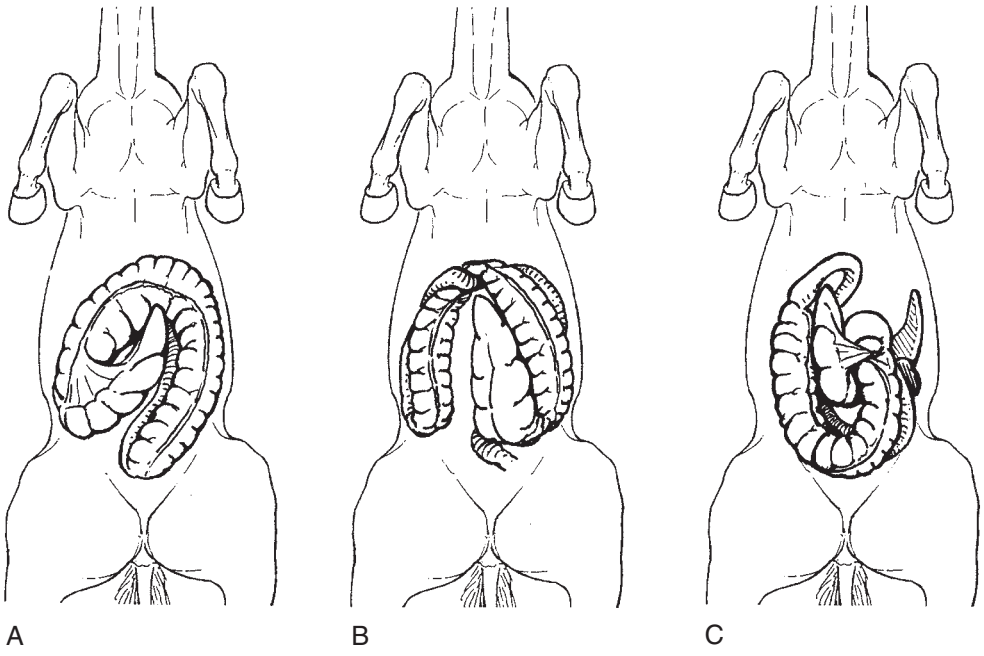


Figure 47-5 Right dorsal displacement of the ascending colon (ventral views). *A,* The normal anatomic relationship of the ascending colon. *B,* The most common direction for a right dorsal displacement is migration of the pelvic flexure in a counterclockwise direction when viewed from the caudal and ventral aspect of the horse at the time of surgery. *C,* Although less common, the ascending colon may develop a right dorsal displacement characterized by a clockwise migration of the pelvic flexure when viewed from the caudal and ventral aspects of the horse at the time of surgery. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

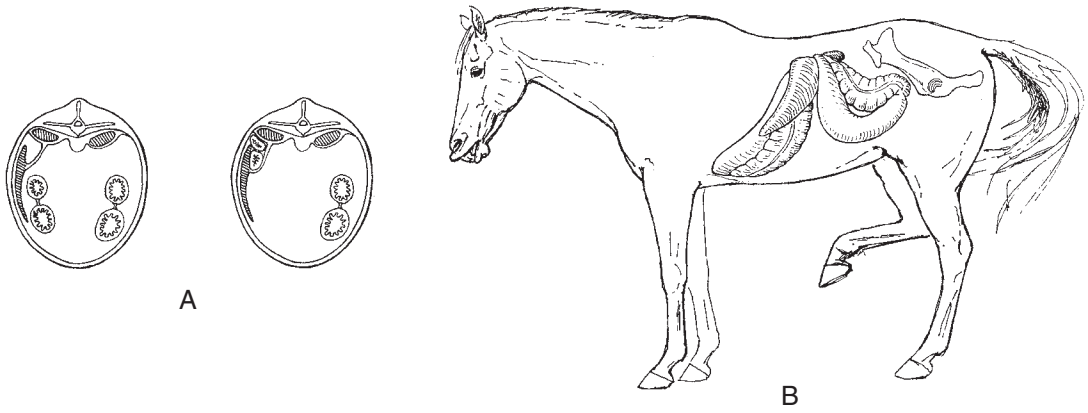


Figure 47-6 *A,* Left dorsal displacement of the ascending colon. The normal anatomic relationships of the colon to the spleen are shown. *B,* The dorsal and ventral colon may displace and become trapped in the nephrosplenic space. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

(2) Left dorsal displacement: Large colon entrapped in nephrosplenic space on left dorsal aspect; if gas distention is severe, may be difficult to determine that colon is entrapped on the ligament; impaction of pelvic flexure may also be palpable, secondary to entrapment

c. Transabdominal ultrasound
 (1) Right dorsal displacement: Usually unremarkable
 (2) Left dorsal displacement: Inability to visualize left kidney due to presence of gas in large colon in left paralumbar fossa
d. CBC: WBC normal; PCV, TP mild to moderate increase secondary to dehydration
e. Chemistry: Increased creatinine and BUN secondary to dehydration; increased GGT from cholestasis secondary to large intestinal distension; more common with right dorsal displacement of large colon

f. Abdominocentesis. Protein concentration and nucleated cell count are usually normal unless there is an increased duration

4. Treatment
 a. Medical
 (1) Pain management (xylazine, detomidine, butorphanol, flunixin meglumine)
 (2) IV fluid therapy to correct dehydration
 (3) No feed/hay until displacement resolves
 (4) Phenylephrine and trotting: For nephrosplenic entrapment only; 10 to 20 mg of phenylephrine diluted with saline administered slowly to cause splenic contraction, jogging or walking to get colon to "bounce" off nephrosplenic ligament
 (5) Phenylephrine and rolling: Rolling under general anesthesia; phenylephrine administered as above. Rolling in the following manner: Start in right lateral recumbency, roll into dorsal recumbency, and hoist the rear legs if possible, roll into left lateral recumbency, roll into sternal, complete by returning to right lateral recumbency
 b. Surgical: Often required
 (1) Correction of displacements: Ventral midline celiotomy and correction of displacement; pelvic flexure enterotomy required if impaction of large colon is present
 (2) Prevention of recurrence: Colopexy not recommended for performance horses; large colon resection; laparoscopic closure of nephrosplenic space; only prevents left dorsal displacement from recurring
5. Prognosis and complication
 a. Prognosis is good
 b. Complications: Recurrence (7% to 10% of cases), endotoxemia, diarrhea, surgery-associated complicatioins include adhesions, incisional infection

D. Large colon torsion
1. Cause and signalment
 a. Any sex, breed, or age. Increased incidence in early postpartum mares; due to sudden increase in space within abdominal cavity, allowing large colon to twist more readily
 b. Cause unknown; changes in motility suspected and could be secondary to parasites or changes in feed type or water intake
 c. Large colon twists on long axis; varies from 270 degrees to 720 degrees of rotation; results in strangulation of large colon obstructing blood flow
 (1) Venous obstruction usually occurs first followed by arterial
 (2) Mucosa becomes black and nonviable
 (3) Serosa becomes purple to gray
 (4) Colon becomes very edematous and fluid filled
2. Clinical signs: Severe colic, acute rapid onset of pain, absent GI sounds, normal to increased heart rate, severe dehydration, gross abdominal distention
3. Diagnosis
 a. NG intubation: Net reflux is typically not obtained
 b. Rectal palpation: Gas-distended large colon; may be so severe that cannot pass the pelvic inlet
 c. Transabdominal ultrasound: Edematous large colon wall and mesentery
 d. CBC: WBC normal to leukopenic; PCV, TP moderate (PCV = 45% to 55%) to severe (PCV = 60% to 70%) increase secondary to dehydration
 e. Chemistry: Increased creatinine and BUN secondary to dehydration, increased lactate secondary to poor perfusion, metabolic acidosis; postpartum mares hypocalcemic; other abnormalities may be present
 f. Abdominocentesis: Protein concentration and nucleated cell count are usually normal unless increased duration
4. Treatment: Surgery
 a. Pain management may not be able to be controlled (xylazine, detomidine, butorphanol, flunixin, meglumine)
 b. IV fluid therapy to correct dehydration
 c. Correction of torsion: Ventral midline celiotomy; pelvic flexure enterotomy to evacuate large colon and assess colon mucosa; resect if large colon is nonviable
 d. Prevention of recurrence: Colopexy not recommend for performance horses; large colon resection
 e. Anti-endotoxic therapies: Endoserum (serum from horse immunized against LPS); polymixin B (2000 U/kg to 5000 U/kg), binds to lipid poly A portion of LPS
5. Prognosis and complications: Prognosis is guarded. Complications include endotoxemia, diarrhea, failure (dehiscence) at anastomotic site, peritonitis, reperfusion injury to large colon, incisional infections, thrombophlebitis, laminitis, DIC, recurrence

E. Right dorsal colitis
1. Cause and signalment
 a. Any sex or breed
 b. Pathophysiology: NSAID (phenylbutazone or flunixin meglumine) administration decreases prostaglandin (PGE_2) production in large colon, resulting in decreased mucosal blood flow and development of ulcers. History of dehydration or decreased water intake may also play a role in the development of right dorsal colitis
 c. May have gastric ulcers in addition to colonic ulcers
2. Clinical signs: Colic (mild to moderate; may be chronic depending on duration of NSAID use), ventral edema or limb edema, diarrhea, fever
3. Diagnosis
 a. NG intubation: No net reflux
 b. Rectal palpation is usually unremarkable

c. Transabdominal ultrasound: Edematous, thickened large colon (usually on right side)
d. CBC: WBC normal to leukopenic; PCV usually normal, slightly increased if dehydrated, TP decreased (hypoproteinemia very common)
e. Chemistry: Increased creatinine and BUN, either prerenal (dehydration) or renal (secondary to NSAID); hypoproteinemia with hypoalbuminemia
f. Abdominocentesis: Protein concentration and nucleated cell count may have increased protein

4. Treatment
 a. Medical treatment
 (1) Pain management (xylazine, detomidine, butorphanol)
 (2) IV fluid therapy to correct dehydration
 (3) Discontinue NSAID medications
 (4) Plasma or hetastarch to help treat hypoproteinemia
 (5) Antiendotoxic therapies: Endoserum (serum from horse immunized against LPS), Polymixin B (2000 U/kg to 5000 U/kg). Binds to lipid poly A portion of LPS
 (6) Misoprostrol (prostaglandin agonist)
 b. Surgery: Indicated if a stricture forms; surgical treatment is not ideal owing to hypoproteinemia, which can decrease healing
5. Prognosis and complications
 a. Prognosis is guarded
 b. Complications: Endotoxemia, diarrhea, stricture formation, peritonitis, adhesions, incisional infection, laminitis

F. Enterolithiasis
1. Cause and signalment
 a. Any sex or breed; more common in Arabians and miniature horses (small colon enteroliths); increased incidence in western (particularly California) and southern states
 b. Predisposing factors: Alfalfa feeding in high amounts
 c. Cause: Nidus (such as wire or string) allows for formation of mineral (Mg and phosphorous) deposits which accumulate over time. Relative GI hypomotility and alterations in intestinal pH
 d. Common sites: Right dorsal colon, transverse colon, small colon
2. Clinical Signs: Mild to moderate chronic colic, severe colic if obstructed; heart rate normal to slightly increased, mild dehydration, diarrhea
3. Diagnosis
 a. NG intubation. Net reflux is typically not obtained
 b. Rectal palpation: Enterolith not palpable, may palpate impaction secondary to enterolith, large colon gas distension, typically unremarkable
 c. Transabdominal ultrasound is usually unremarkable
 d. CBC: WBC normal, PCV, TP mild increase secondary to dehydration
 e. Chemistry normal; protein and nucleated cell count on abdominocentesis normal
 f. Abdominal radiographs: Presence of radiopaque enterolith will support diagnosis; not ruled out if not seen on radiograph
4. Treatment: Surgery
 a. Pain management (xylazine, detomidine, butorphanol, flunixin meglumine)
 b. IV fluid therapy to correct dehydration
 c. Abdominal exploratory enterotomy to remove enteroliths; enteroliths may be multiple; have a tetrahedral shape if multiple as they roll into each other changing shape
5. Prognosis and complications
 a. Prognosis is good
 b. Complications: Recurrence, diarrhea, rupture of large colon, peritonitis, adhesions, incisional infection, hemorrhage from enterotomy

VI. Disorders of the small colon and rectum
A. Anatomy of small colon
1. Mesocolon long orally but short aborally (including mesorectum), which limits ability to exteriorize small colon completely during ventral midline celiotomy
2. Two teniae are present: Mesenteric, antimesenteric. Enterotomies are performed antimesenteric band due to less vasculature

B. Small colon impaction/obstructions
1. Cause and signalment
 a. Any sex. Arabians, miniature horses, and ponies overrepresented
 b. Some obstructions (e.g., foreign body such as ropes) may have increased incidence in younger horses
 c. Luminal obstructions secondary to meconium, fecolith, enterolith, foreign body (e.g., wood, ropes), feed or hay impaction. Poor dentition, poor-quality hay, inadequate water supply, and *Salmonella* play a role
2. Clinical signs
 a. Colic: Mild to moderate with feed impaction; moderate to severe with fecolith or enterolith (history of intermittent colic). If gas and fluid cannot pass, pain is severe
 b. Other signs include gross abdominal distension, tenesmus, mild to moderate dehydration
3. Diagnosis
 a. NG intubation. No net reflux obtained unless severe distension
 b. Rectal palpation: Impaction felt rectally (firm tube-like structure), mucosa edematous; fecoliths can be palpated
 c. CBC/chemistry: Normal; PCV, TP increased secondary to dehydration
 d. Transabdominal ultrasound. Not specific; distended loops of intestine

e. Abdominocentesis: Protein concentration and nucleated cell count normal unless a fecolith-enterolith compromises small colon, then mild increases in protein or cell count

4. Treatment
 a. Medical: Pain management (xylazine, detomidine, butorphanol, flunixin meglumine), IV fluids, enteral fluids, laxatives (mineral oil, Mg sulfate, psyllium, DSS); no feed or hay until impaction passes
 b. Surgical: Enema (by surgical guidance only) and manual extraluminal breakdown of impaction; Enterotomy on antimesenteric taenia band; remove fecolith, enterolith, foreign body
5. Prognosis and complications
 a. Prognosis is fair to good
 b. Complications: Endotoxemia, diarrhea, adhesions, incisional infection

C. Meconium impaction
1. Cause and signalment
 a. Young foals up to 72 hours after birth
 b. Meconium is first feces passed after birth, which can become firm and impacted in foals. Made up of amniotic fluid, cellular debris, and glandular secretions
 c. Dehydrated, weak, premature, or septic foals may be at risk; however, a healthy foal can also have a meconium impaction
 d. No breed or sex predilections
2. Clinical signs
 a. Persistent tenesmus can be confused with straining to urinate, which would be a sign of ruptured bladder
 b. Mild to moderate colic; foal will roll up on his or her back
 c. Reluctance to nurse or infrequent nursing
 d. Failure to see passage of meconium. May pass some meconium initially, then stop
 e. Gross abdominal distention
3. Diagnosis
 a. NG intubation: Typically no reflux is present
 b. Rectal examination: Genital digital examine may reveal feces in rectum
 c. Abdominocentesis: Protein and nucleated cell count normal
 d. Radiographs: Contrast enema to visualize extent of impaction; plain films reveal dilated gas filled large bowel
4. Treatment
 a. Medical
 (1) Ideal: Foals are not typically good surgical candidates and have increased risk of developing adhesions
 (2) Enema: Warm, soapy water enemas best, particularly if need to be repeated numerous times; use Fleet enemas with caution as they can result in hyperphosphatemia; Acetylcystine retention enema left in place for approximately 20 minutes, helps break down impaction, can repeat
 (3) Laxatives via NG tube: Mineral oil, milk of magnesia, DSS; use with caution if small bowel distention is present
 (4) IV fluids if dehydrated and not nursing. May need to supplement with dextrose
 (5) Pain management: Butorphanol, flunixin meglumine (can cause ulcers, especially if not nursing)
 b. Surgical
 (1) Only if medical therapy has failed; needed in less than 25%
 (2) Impaction manually evacuated through external massage of small colon via ventral midline celiotomy
 (3) Care must be taken with delicate mesentery and intestine
 (4) Pelvic flexure enterotomy can be performed if severe impaction is present oral to the meconium impaction
5. Prognosis and complications
 a. Medical prognosis good; most resolve without surgery
 b. Surgical prognosis guarded to fair; adhesions can form. Increased risk for sepsis, particularly if enterotomy is necessary

D. Rectal tears
1. Cause and signalment
 a. Causes: Iatrogenic (secondary to rectal palpation), breeding accident, rectal tumor
 b. Grades
 (1) Grade I: Mucosa or submucosa
 (2) Grade II: Muscularis (mucosa/submucosa herina)
 (3) Grade III: Mucosa, submucosa, muscularis
 (a) Subgrade A: Ventral or side tear, covered only by serosa
 (b) Subgrade B: Dorsal tear, covered by mesocolon. Most common because of location of the ovary
 (4) Grade IV: Penetrates all four layers into peritoneal cavity
2. Clinical signs: Blood on sleeve after rectal palpation, colic, endotoxemia if grade IV tear (tachycardia, injected or toxic mucous membranes, prolonged capillary refill time, tachypnea, fever)
3. Diagnosis
 a. Rectal palpation
 (1) After caudal epidural placement and appropriate restraint
 (2) Recommended to palpate without gloved sleeve
 (3) Can palpate tear, and presence of blood will be noted
 b. Endoscopy: Visualize tear and determine if full thickness
 c. Abdominocentesis
 (1) Protein concentration and nucleated cell count: Normal if grade I or II; mildly increased with grade III, increased with grade IV

(2) Grade IV tears have intracellular and extracellular bacteria
(3) Gross fecal material with grade IV tears

4. Treatment and prevention
 a. Prevention: Sedation (especially nervous horse or painful colic), twitch, stocks, lidocaine administered per rectum (60 mL), epidural
 b. Initial treatment once a tear is suspected
 (1) Sedate, administer caudal epidural, twitch, and place in stocks
 (2) Clean out gently to assess tear: No glove and lots of lubrication
 (3) Pack with cotton in an orthopedic stockinet (with or without bactericidal agent – povidone iodine); pack 15 to 20 cm cranial to defect and go to anal sphincter; may suture or pack to retain packing
 (4) Administer broad spectrum antibiotics, NSAIDs, mineral oil via NG tube, tetanus toxoid
 (5) Inform owners; refer for surgery
 c. Conservative treatment
 (1) For I and II tears: Antibiotics, anti-inflammatories, stool softeners (mineral oil); grade II may form diverticulum
 (2) For IIIb tears
 (a) Clean out manually every 1 to 2 hours for 24 to 48 hours and then frequently after that
 (b) No food for 48 hours, then follow with green grass and wet alfalfa pellets only
 (c) Use epidural during evacuation
 (d) Lidocaine, lots of lube and no glove to evacuate
 (e) Give antibiotics (penicillin, gentamicin, metronidazole), NSAIDs, and mineral oil via NG tube
 d. Surgical treatment
 (1) Direct suturing or stapling
 (a) Laparoscopic: Technically difficult, may not work with grade IIIb due to mesocolon, will not allow for evacuation of the large colon
 (b) Transrectally: Technically difficult, staples do not tend to hold, abscess or strictures can form
 (2) Diverting colostomy
 (a) Loop colostomy: Standing with local block and sedation; general anesthesia will allow for evacuation of large colon; allows for reversal. Need antibiotics, NSAIDs, and stool softeners
 (b) End colostomy. Similar to loop colostomy except end to skin and therefore cannot reverse
 (3) Temporary indirect rectal liner
 (a) Done via ventral midline or flank; typically done for grade III. Tear sutured to prevent becoming grade IV
 (b) Liner-ring should slough 10 to 14 days postoperatively
 (c) Pelvic flexure enterotomy performed to evacuate colon if ventral midline approach is used
 (d) Continue with antibiotics, NSAIDs, and stool softeners
 (4) Abdominal lavage
 (a) Necessary for grade IV; drain placed standing if surgical procedure is done standing
 (b) Lavage with 10 to 20 L for 3 to 4 days
5. Complications depend on grade and treatment; lower grades could progress to more severe tears. Complications include endotoxemia, laminitis, colic (secondary to impaction). Problems associated with stoma of colostomy: Mutilation of stoma by horse, dehiscence, abscess formation, impaction at colostomy site, adhesions. Problems associated with rectal liner: Premature separation of rectal liner, conversion of grade III to grade IV, necrosis of the liner attachment
6. Prognosis
 a. Grade I and II: Good to excellent if managed correctly
 b. Grade III and IV: Guarded to poor, less than 20% chance for survival. IIIb worse than IIIa, as IIIb (44% alone; 60% a and b) likely to progress to IV. Grade IV should be euthanized unless immediate care can be given
 c. Prognosis depends on minimal contamination, and proper initial treatment as soon as the tear is recognized

E. Rectal prolapse
1. Causes and signalment
 a. Causes: Straining from colic (small colon impaction), diarrhea, dystocia, or intestinal parasites; proctitis, rectal tumor, rectal foreign body
 b. More common in females than males; any age.
 c. Types
 (1) Type I: Only rectal mucosa
 (2) Type II: Complete prolapse of all or part of the rectal ampulla
 (3) Type III: Small colon intussuscepts into rectum in addition to type II
 (4) Type IV: The peritoneal rectum and variable amount of the small colon will prolapse as an intussusception through the anus
2. Clinical signs: Can visualize prolapse, colic with type III and IV
3. Diagnosis: Visualization of prolapse; protein concentration and nucleated cell count on abdominocentesis is increased with peritonitis (especially type III and IV); increases in red blood cells also present indicating damage to mesocolon
4. Treatment
 a. Conservative treatment: Treat underlying cause (e.g., diarrhea), antiinflammatories,

caudal epidural to prevent straining, topical treatment to decrease edema, laxatives, soft feeds, no hay
b. Submucosal resection indicated if prolapsed tissue is devitalized or if recurs after conservative treatment
c. Manual reduction: Monitor for compromise to small colon or rectum; can be accompanied by laparoscopy of mesocolon and small colon

5. Prognosis and complications
a. Prognosis is good to fair for type I and II
b. Prognosis is guarded to poor for type III and type IV, and depends on the amount of vascular damage present
c. Complications: Worsening of prolapse, peritonitis, damage to mesocolon and associated vessels resulting in necrosis of small colon or rectum, impaction

DISORDERS OF THE SKIN

I. Wound healing
A. Occurs by two processes
1. Regeneration
a. Replacement of damaged with normal tissue. Heals by migration and proliferation of epidermal cells with little to no inflammation
b. Partial-thickness wounds heal this way
2. Repair
a. Full-thickness wounds heal this way
b. Three phases
(1) Acute inflammation
(a) Brief vasoconstriction followed by vasodilation to allow for diapedesis of cells, fluid, and protein
(b) Clot formation occurs
(c) Leukocytes recruited to fight infection and clean up damaged tissue
(2) Cellular proliferation
(a) Occurs at 3 to 5 days post wound
(b) Fibroblast, endothelial cells, and epithelial cells migrate into wound
(c) Granulation tissue forms: Fibrin clot replaced; fibroblast replaced by myofibroblasts, which assist with wound contraction
(d). Greatest rate of maturation occurs at 7 to 14 days where it gains the most rapid tensile strength
(e) Angiogenesis occurs, allowing for new capillaries to form
(f) Epithelialization starts 24 to 48 hours after injury occurs but might not be visible until 4 to 6 days after injury. Failure of epithelialization can occur because of excessive granulation tissue or granulation tissue is poor quality
(3) Remodeling
(a) Wound contraction occurs (via myofibroblast)
i. Lag phase: Retraction of wound briefly increasing size, allowing for fibroblast to fill in spaces
ii. Rapid contraction phase
iii. Slow contraction phase: Decreases the number of myofibroblasts
(b) Contraction ends when contact inhibition halts epithelialization and contraction
(c) Conversion of granulation tissue to scar

B. Factors influencing wound healing
1. General health. Protein important to wound healing
2. Blood supply, oxygenation, anemia
a. Need microcirculation to deliver oxygen and nutrients
b. Hypovolemia, anemia, and shock all affect wound healing
3. Location
a. Healing above distal limb is usually better than below
b. Proposed reasons for decreased healing in distal limbs: Decreased blood supply, thicker epidermis, increased motion, increased contamination, poor contraction of distal limb wounds
4. Vitamins and minerals
5. NSAIDs: Use is controversial as inflammation is important to repair; however their use may be important to help treat chronic nonhealing wounds
6. Use of corticosteroids
a. Topical and systemic administration will retard wound repair
b. Use is indicated in wounds with chronic proliferative granulation tissue
7. Use of bandages: Although keeps wound clean, will keep the wound environment moist and may result in excessive granulation tissue

C. Skin grafts
1. Types of graft
a. Source
(1) Autograft: From same individual
(2) Allograft: From different individual, but same species
(3) Xenograft: From different species
b. Thickness
(1) Full thickness: Composed of epidermis and entire dermis, has hair and glandular structures. Sheet, mesh, and island graft are examples. Types of island grafts: Pinch, punch, and tunnel grafts
(2) Split thickness: Composed of epidermis and part of dermis; can be thin, intermediate, or thick
(3) Rate of healing is inversely proportional to thickness of graft
(4) Requires dermatome and can be challenging to collect
2. Physiology of graft acceptance
a. Recipient bed characteristics
(1) Uninfected wound

(2) Must have healthy granulation tissue (no exposed bone, tendon, or cartilage; no excessive fat)
(3) Needs good vascular supply
b. Phases of graft acceptance
(1) Serum imbibition: Method that graft gets nutrition during early period (0 to 48 hours); serum is source of nutrients since no blood vessel at graft yet
(2) Revascularization occurs by two mechanisms
(a) Inosculation: Connection of host vessels to existing vasculature
(b) Neovascularization: Ingrowth of new vessels into graft from recipient bed
(3) Organization: Starts around 4th day, and by 7th or 8th day graft-host connection is established by infiltration of fibrin layer by fibroblast
(4) Graft contraction: Shrinkage of graft; full-thickness graft contracts more than split thickness
3. Reasons for graft failure: Fluid accumulation, infection (main cause of graft failure), motion, poor vasculature supply, inappropriate granulation tissue bed preparation
4. Aftercare of post graft placement
a. Bandage with nonadherent layer and a bulky second layer to minimize movement. May need cast to help decrease movement
b. Monitor for signs of infection

II. Sarcoids
A. Causes and signalment
1. Most common skin tumor of horses, donkeys, and mules
2. Usually not metastatic, but tumors are locally invasive
3. Adults: Most initially develop when younger than 7 years old
4. Any breed can be affected. More common in Appaloosa and Arabian horses
5. No seasonal or geographical predilections have been reported
6. Cause is unknown; however, it is suspected that the bovine papillomavirus plays a role in development
B. Clinical signs
1. Four forms of sarcoids
a. Verrucous: Wartlike in appearance, dry and hornlike, diameter smaller than 6 mm
b. Fibroblastic: Most aggressive form, most variable in appearance. May be intradermal mass covered with skin or ulcerative and proliferative
c. Mixed: Usually combination of fibroblastic and verrucous
d. Occult: Slow growing, appears as thick, hyperkeratotic plaque
2. Lesions can occur anywhere on body. Most common is limbs, ventral abdomen, periocular, and ears
3. Lesions can be single or multiple
C. Diagnosis
1. Histopathologic: Benign fibroblast-like cells; may be mixed with inflammation
2. Differential diagnosis: Nodular necrobiosis (eosinophilic granuloma), exuberant granulation tissue, habronemiasis, other tumors (mast cell, melanoma, squamous cell carcinoma)
D. Treatment
1. Surgical excision
a. Primary treatment only when wide margins of normal appearing tissue can be taken
b. When wide margins are not taken, surgery alone results in 50% recurrence within 6 months
c. Usually recommend with combination therapy
2. Cryotherapy
a. Need at least three freeze-thaw cycles (-30° C)
b. Reported success rates around 70%
c. Recheck in 3 to 6 weeks and repeat treatment if needed
3. Immunotherapy with baacille Calmette-Guérin
a. Overall success is reported to be 59%
b. Increased success with periocular lesions (85%)
c. Can have life-threatening anaphylactic reaction to treatment
4. Radiotherapy
a. Involves placement of ^{192}Ir wires around the lesion
b. Requires appropriate equipment and facilities for radiation.
c. Reported remission rates for 1 year of 87% to 100%
5. Laser therapy: CO_2 laser for removal and photoablation successful in 81%
6. Topical chemotherapy
a. Xxterra: Indian blood root has anecdotal success
b. 5-Fluorouracil (5-FU): Inhibits nucleic acid synthesis, but can only be applied to small tumors
c. Reported success varies and will not respond as well if tumor recurs
7. Intratumoral chemotherapy: Cisplatin in sesame oil, dosage 1 mg/cm^3, repeated 3 to 4 times at 2- to 3-week intervals; 1-year remission rate of 87%
E. Prognosis
1. Guarded for complete resolution: High recurrence rate; requires combined therapy; if recurs, more difficult to treat the second time
2. Complications: Recurrence, healing of surgical wound, particularly if poor margins, inflammation secondary to treatment, rare metastasis

III. Squamous cell carcinoma
A. Cause and signalment
1. Second most common skin tumor of horses, donkeys, and mules
2. Locally invasive, slow to metastasize; in adults
3. Any breed; more common in light-color breeds, particularly Appaloosas

B. Clinical signs
 1. Lesions begin as slightly raised, ulcerative lesion and progress to proliferative ulcerative lesions
 2. Common sites: Face (eyes, sinus), penis, prepuce, vulva (may be intradermal mass covered with skin or ulcerative and proliferative)
 3. Metastasis typically occurs in local lymph nodes

C. Diagnosis
 1. Histopathologic: Squamous cells with nuclear changes suggestive of neoplasia
 2. Differential diagnosis: Nodular necrobiosis (eosinophilic granuloma), exuberant granulation tissue, Habronemiasis, other tumors (mast cell, melanoma, sarcoid)

D. Treatment
 1. Surgical excision: Wide margins necessary; may require enucleation or phallectomy to get aggressive wide margins
 2. Cryotherapy: Two freeze-thaw cycles
 3. Radiation therapy: Cobalt or linear accelerator can be used but requires multiple treatments under general anesthesia; success rates 73% to 100%
 4. Laser therapy: CO_2 laser best when combined with surgical resection
 5. Topical chemotherapy with 5-FU: Inhibits nucleic acid synthesis; good for small tumors
 6. Intratumoral chemotherapy: Cisplatin in sesame oil, dosage 1 mg/cm^3, repeated 3 to 4 times at 2- to 3-week intervals. 65% success rate when used alone and up to 85% when used in combination therapies

E. Prognosis guarded. Complications include recurrence, healing of surgical wound (particularly if poor margins), inflammation secondary to treatment, metastasis

IV. Melanoma

A. Cause and signalment
 1. Occur most commonly in gray or white horses
 2. Adults usually (rarely congenital)
 a. Typically older than 6 years
 b. Number of melanomas may increase with age. Up to 80% of gray horses will have a melanoma by the age of 15 years

B. Clinical signs
 1. Usually multiple tumors are present
 2. Common sites: Underside of root of tail, perianal-perineal region; less frequently eye, abdomen, thorax
 3. Metastasis: Uncommon, can become systemic; follows lymphatics
 4. Lesion appearance is nonpainful, spherical mass, smooth, alopecic, raised, or ulcerative; amelanotic or black to brown
 5. Most are slow growing but can rapidly increase in size

C. Diagnosis based on histopathology. Differentials include exuberant granulation tissue, habronemiasis, and other tumors (mast cell, squamous cell carcinoma, sarcoid)

D. Treatment
 1. Benign neglect and monitor tumor size closely
 2. Surgical excision: Indicated if defecation is obstructed or if lesion is changing and becoming aggressive
 3. Cimetidine: Histamine$_2$ receptor antagonist. Treated with 2.5 mg/kg of body weight orally (PO) every 8 hours. Variable response
 4. Radiation therapy: Cobalt or linear accelerator can be used but requires multiple treatments under general anesthesia

E. Prognosis
 1. Fair to guarded
 2. Complications: Recurrence, healing of surgical wound (particularly if poor margins), inflammation secondary to treatment, metastasis, development of more tumors

V. Cutaneous habronemiasis

A. Causes and signalment
 1. Due to aberrant intradermal migration of larvae of the stomach worm *Habronema muscae, Habronema majus,* and *Drachia megastoma*
 2. Larvae deposited into moist, traumatized skin or wounds
 3. Most common during fly season. Also known as summer sores
 4. Any breed or age can be affected
 5. Larvae cause a significant inflammatory response, and lesions can persist even after parasite is killed
 6. Once develops in a horse, yearly recurrence is common

B. Clinical signs
 1. Lesions resemble exuberant granulation tissue with small yellow granules present within the lesion; mild to severely pruritic
 2. Common sites: Distal limbs, penis (urethral orifice), eye

C. Diagnosis
 1. Histopathologic: Presence of live or dead larvae, eosinophilia within tissue
 2. Differential diagnosis: Nodular necrobiosis (eosinophilic granuloma), exuberant granulation tissue, sarcoid, squamous cell carcinoma, phythiosis

D. Treatment
 1. Surgical excision: To debride the inflammatory tissue and remove larvae (dead or alive)
 2. Medical: Ivermectin, topical corticosteroids (decrease inflammation); systemic steroids may be necessary (prednisolone at 1 mg/kg once a day for 10 to 14 days, then taper), antiinflammatories. Miscellaneous topical therapies (organophosphates, dimethyl sulfoxide, dexamethasone, antibiotics, antiinflammatories, ivermectin), cryotherapy, fly control

E. Prognosis: Fair; recurrence is a complication

VI. Pythiosis

A. Causes and signalment
 1. Due to infection of the fungal-like organism *Pythium insidiosum*. Infection occurs through open wounds or breaks in the skin. Found in water sources; common in the South and in tropical regions. Also known as swamp cancer

2. Any breed or age; most common in late summer and fall
3. Very locally aggressive; considered a zoonotic disease

B. Clinical signs
1. Lesions resemble exuberant granulation tissue with kunkers present (classic lesion of calcified blood vessels). Lesions often become necrotic due to calcification of blood supply. Lesions are severely pruritic
2. Common sites include distal limbs, ventral abdomen

C. Diagnosis: Presence of kunkers, fungal culture. Differential diagnoses include habronemiasis, exuberant granulation tissue, sarcoid, squamous cell carcinoma

D. Treatment
1. Surgical excision: Aggressive debridement to remove all affected tissue; difficult to get all tissue because of common locations
2. Antifungal: Not very helpful; pythium is not a true fungus. Can try sodium iodine, amphotericin B, or fluconazole systemically
3. Vaccination: Made from pythium lesions; injected SC, requires injection 1, 7, and 21 days. Alters immune response to cause body to make the appropriate response to the lesion and help decrease size or eliminate the lesion
4. Other treatments include antiinflammatories, cryotherapy, CO_2 laser treatment

E. Prognosis
1. Poor to guarded: Resolution possible if treated early and aggressively
2. Complications include incomplete resolution and invasion into supportive structures (e.g., tendon sheath, tendons, abdominal cavity), reaction to vaccine

VII. Exuberant granulation tissue

A. Causes and signalment
1. Secondary to wound usually on the distal limb
2. More common in horses than ponies; any breed or age
3. Delays wound healing. Believed to be secondary to chronic inflammation of the wound bed and inability to move into the next stage of wound healing

B. Clinical signs: Raised, proliferative granulation tissue; secondary superficial infection may be present. Common involvement with *Pseudomonas*

C. Diagnosis: Rule out other differentials (habronemiasis, pythium, sarcoid, squamous cell carcinoma)

D. Treatment
1. Surgical excision, debridement of granulation tissue
 a. No local anesthetic agent needed as lacks nerve supply
 b. Will usually bleed so compression bandage is usually needed
 c. Multiple debridements may be needed
2. Topical steroids
 a. Decreases inflammation and allows for wound contraction
 b. Decreases epithelialization so prolonged treatment is not recommended

E. Prognosis: Good; Requires attentive care during healing and may require multiple debridements. Complications: Recurrence; infection with habronema larvae

MUSCULOSKELETAL SYSTEM

I. Introduction. Lameness is one of the most common problems that occur in horses, and its treatment requires knowledge of anatomy and the numerous conditions that can cause it. This section will cover a brief approach to the evaluation of a lame horse and a description of the most common causes of musculoskeletal disease in horses.

II. Lameness evaluation. An evaluation should proceed in the following order:

A. A thorough history should be obtained covering the following pertinent facts
1. Duration of lameness?
2. Severity of lameness?
3. Acute onset or gradual onset?
4. What is the horse used for, and what will the horse be used for?
5. What was the horse doing when the lameness was first observed?
6. What has the horse been doing since lameness observed (e.g., confined to stall, turned out at pasture, raced)?
7. If any medications have been administered and the response to those medications (did lameness improve, stay the same, worsen)?
8. When did the horse last have its feet trimmed or shod?

B. Observe horse from a distance to identify asymmetry of limbs, swellings, how the horse uses its limbs, and whether it is willing to bear weight appropriately when at rest on all four feet
1. A complete physical examination
2. Musculoskeletal examination, including the following:
 a. Palpation of all limbs and joints (compare with contralateral limb) to identify swelling, heat, joint, or synovial bursal effusions, pain, discomfort, range of motion of joints; application of hoof testers to all four feet
 b. Watching the horse move at the walk
 c. Watching the horse move at the trot
 (1) Initially in a straight line on a firm surface
 (2) Then either in a circle on a lunge line or in a straight line on a soft surface
 (3) Following flexion tests to attempt to localize the lameness to a region of particular limb

C. Apply a grade to the lameness (American Association of Equine Practitioners Lameness Grading System of 0 to 5) so that a consistent record of the examination can be maintained
1. Grade 0: No apparent lameness
2. Grade 1: Lameness difficult to observe

3. Grade 2: Difficult to observe at a walk or trot in a straight line
4. Grade 3: Consistently observable at a trot at all times
5. Grade 4: Obvious lameness, observed at the walk
6. Grade 5: Minimal weight-bearing lameness

D. The lameness, if not localized by this stage, should be identified using diagnostic anesthetic techniques. If nerve blocks are used, these should be started distally and proceed proximally up the limb (Figures 47-7 and 47-8)
1. Palmar-plantar digital nerve block: Will consistently anesthetize heel region, navicular bursa and bone, sole of hoof, and other structures in caudal portion of hoof capsule
2. Abaxial sesamoid nerve block: Will anesthetize everything distal to the site of anesthesia on the palmar-plantar aspect of the limb and everything distal to the proximal-midportion of the first phalanx dorsally
3. Low 4 point (6 point in hindlimb): Will anesthetize everything from the distal cannon bone distally
4. High 4 point: If high enough will anesthetize the origin of suspensory ligament, palmar aspect of limb from that point distally, flexor tendons, and everything on dorsal surface from mid-proximal cannon bone distally
5. Individual nerve blocks (radial, ulnar, median, tibial, or peroneal) individually anesthetized; results harder to interpret owing to large areas that these nerves supply
6. Individual joints can be anesthetized but do not need to be performed in any order as these will not interfere with other nerve blocks. Help to identify a specific joint as origin of lameness

E. Once localized, imaging techniques can be used to identify any abnormalities
1. Radiographs for skeletal structures
2. Ultrasound for soft tissues
3. CT (particularly useful for fractures or skulls)
4. MRI (useful for soft tissue and skeletal structures, but often limited to distal limb)

F. If not possible to localize lameness (e.g., multilimb lameness, horse will not tolerate diagnostic anesthetic techniques), nuclear scintigraphy (bone scan) performed to identify regions of osteoblastic activity or soft tissue inflammation

G. Appropriate therapy determined following identification of the disease process

III. Fractures

A. Long-bone fractures in adult horses often have a poor prognosis because of the severity of the injury and resultant secondary damage to

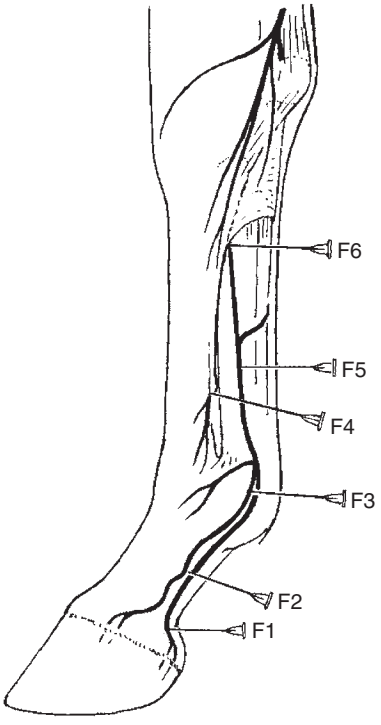


Figure 47-7 The lateral aspect of the left distal forelimb, with location of needle placement for perineural anesthesia. F1, distal palmar digital nerve block; F2, proximal palmar digital nerve block; F3, abaxial sesamoid block; F4, low metacarpal nerve block; F5 and F6, high palmar nerve block. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

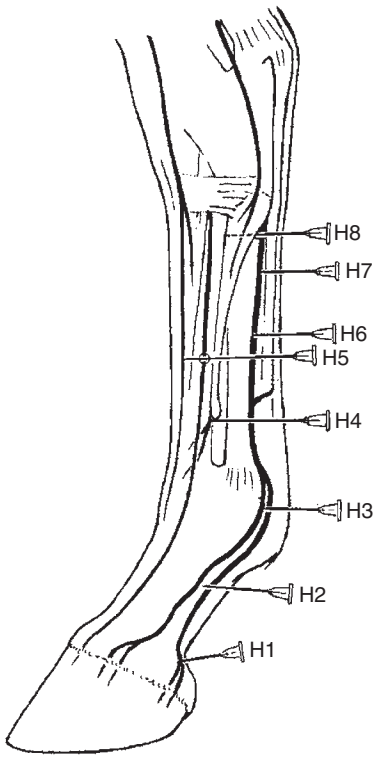


Figure 47-8 Lateral aspect of the left distal hindlimb, with location of needle placement for perineural anesthesia. H1, low plantar digital nerve block; H2, high plantar digital nerve block; H3, abaxial sesamoid block; H4, low metatarsal nerve block; H5, mid third metatarsal fibularis nerve block; H6 and H7, high plantar nerve block; H8, high metatarsal nerve block. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

associated muscles, tendons, vascular structures, and joints. Although many implants have been created specifically for horses, most are not strong enough to withstand forces that they will be exposed to over time for healing to occur. Fractures of cuboidal bones, phalangeal bones, and ulna can sometimes be repaired

B. Causes and signalment: All ages and breeds; traumatic in origin
C. Clinical signs associated with a fracture: Severe lameness, usually acute onset; soft tissue swelling, crepitus, or instability upon palpation
D. Diagnosis: Radiographs are essential to identify the configuration of the fracture; assess injured area to identify any wounds (open fractures have a poorer prognosis)
E. Treatment
 1. Immobilize injured limb (Robert Jones bandage and splints if applicable)
 2. Medical therapy for shock (IV fluids, analgesics, and sedatives to prevent further injury)
 3. Appropriate form of fracture fixation (internal fixation, transfixation casting, bandaging, conservative options). To improve the chances of successful treatment, bone grafts (autografts from tuber coxae, proximal humerus, or tibia) can be used; regional IV limb perfusions with antibiotics or antibiotic-impregnated polymethylmethacrylate can maintain high levels at fracture site
F. Prognosis and complications
 1. Prognosis
 a. Comminuted, open fractures with articular components have worst prognosis; involvement of long bones decreases prognosis
 b. Age and weight of the horse
 2. Contralateral limb overload injuries: Laminitis, angular limb deformity, suspensory ligament breakdown
 3. Fracture-related complications: Infection of implants or surgical site, implant loosening or failure, nonunion or delayed union, osteoarthritis, chronic lameness

IV. Stress fractures
A. Causes and signalment
 1. Accumulation of microdamage related to training or racing; humerus, radius, tibia, 3rd metacarpal, or metatarsal bones most commonly affected
 2. Usually in young racehorses but can be seen in older racehorses, particularly following a period of rest
B. Clinical signs
 1. Lameness improves with rest; returns when training or racing resumes
 2. Joint effusion and discomfort associated with flexion tests
C. Diagnosis: Diagnostic anesthetic techniques nuclear scintigraphy used; radiographs often nondiagnostic
D. Treatment: Prolonged periods of rest (up to 6 months) and pasture turnout before gradual return to training; scintigraphy to monitor response
E. Prognosis and complications
 1. Prognosis is good if adequate rest is provided and bone remodeling occurs
 2. Continuation of training can lead to formation of complete fracture (e.g., condylar fracture, tibial fracture); dorsal cortical fractures or saucer fractures of 3rd metacarpal bone

V. Injuries to joints (osteoarthritis [OA] and synovitis): Synovitis is inflammation of synovial membrane secondary to trauma; causes release of inflammatory mediators within joint; leads to cartilage degeneration and formation of OA
A. Causes and signalment
 1. Final result of multiple, repetitive low-grade injury to a joint and its periarticular structures or the end result of a single, acute traumatic event
 2. Tends to be older horses
 3. Seen in younger performance horses
B. Clinical signs
 1. Variable lameness related to severity and joint affected. If high-motion joints are involved, lameness is often more severe. Gradual onset
 2. If mild, lameness often improves following light work (appears to warm out of lameness). Following period of rest, lameness will often be worse
 3. Joint effusion, decreased range of motion, and discomfort when flexing joint.
C. Diagnosis
 1. Clinical signs and history: Diagnostic anesthetic techniques should be performed to localize lameness to particular joint
 2. Arthrocentesis often reveals more watery synovial fluid (subjective), but other parameters (TP, WBC) within normal limits
 3. Radiographic signs: Periarticular osteophytes, subchondral bone sclerosis, or lysis, asymmetrical thickness of joint space (collapse of joint), advanced remodeling or ankylosis
D. Treatment
 1. Analgesics such as phenylbutazone (or other NSAIDs). Often requires use any time the horse is active
 2. Management changes such as allowing as much turnout as possible, retiring the horse from active competition, reducing the horse's workload
 3. Intra-articular medications such as steroids with or without hyaluronic acid. Often need to be repeated; response tends to decrease with subsequent injections. Can accelerate cartilage damage. OA of the lower hock joints can often be managed successfully with this therapy for years, unlike most other joints
 4. Joint supplements such as glycosaminoglycans; hyaluronic acid given systemically; or oral nutraceuticals such as chondroitin, glucosamine, or hyaluronan-containing products

5. Surgical arthrodesis: Only an option for proximal interphalangeal, metacarpophalangeal-metatarsophalangeal, distal tarsal and carpal joints, but will often produce only a horse that is pasture sound

E. Prognosis and complications: Varies with joint and severity. If high-motion joints are affected, there is usually a permanent decrease in soundness

VI. Tendon and ligament injuries

A. Causes and signalment
1. Tendons are mainly composed of type 1 collagen and water
2. Injuries or tendonitis usually seen in performance horses but can occur in any horse. Use of horse predisposes certain tendons to injury more than others
3. Tendonitis is either the result of cumulative episodes of microdamage, which eventually result in enough damage for clinical signs to become apparent, or of a one-time, acute overload or strain injury
4. Racehorses usually injure their superficial digital flexor tendon or suspensory apparatus (includes suspensory ligament, proximal sesamoid bones and distal [straight, oblique, and cruciate] sesamoidean ligaments). Deep digital flexor tendon injuries occur much less frequently

B. Clinical signs seen with tendonitis (affects tendons) or desmitis (affects ligaments)
1. Swelling and heat over affected region with or without enlargement of tendon
2. Pain upon palpation of injured region: Often bilateral, so contralateral limb should be examined closely
3. Variable lameness: Initially this can be severe but can improve markedly over 1 to 2 weeks, even with severe injuries
4. Alteration in function of limb: Collateral ligament injury will result in mediolateral instability of joint if severe enough; suspensory ligament breakdown will result in a fetlock that will hit the ground when bearing weight

C. Diagnosis of tendon injury
1. Clinical signs and history
2. Palpation and associated pain response
3. Ultrasonographic evaluation
 a. Important for prognosis and to allow accurate exercise recommendations to be made: Allows identification of abnormal fiber alignment; allows identification of hypoechoic regions of tendon; allows subtle changes in size of tendon to be identified and compared with contralateral limb (particularly useful when evaluating the suspensory ligament); allows lesion to be accurately defined (length of tendon involved, cross sectional area of abnormal tendon)
 b. Reevaluations can be performed to assess response to therapy so that treatment recommendations can be adjusted if necessary

D. Treatment
1. Antiinflammatories such as NSAIDs in the early stages. Cold hosing can also help decrease inflammation, before bandaging
2. Support via heavy bandages or Robert Jones bandage to limit movement and prevent further damage; supplemented with splints or cast if instability is severe
3. Exercise restriction: Varies from strict stall rest to decreasing activity level
4. Controlled rehabilitation program: As long as 18 months of a gradually increasing exercise program, with periodic ultrasound rechecks to monitor
5. If tendon is injured within a digital sheath, chronic tenosynovitis may result, which can inhibit or delay healing. Annular ligament desmotomy can reduce the degree of inflammation by decreasing the pressure within the digital sheath

E. Prognosis and complications
1. Superficial or deep digital flexor tendonitis: Poor prognosis for return to an athletic sport such as racing. For less demanding endeavors, horses can recover and return to previous use, but risk of reinjury remains high
2. Desmitis of the suspensory ligament: Variable prognosis depending on part of ligament injured; return to previous level of activity is possible
3. Tendon injuries within synovial structures: Poor prognosis
4. Risk of reinjury is high as the healed tendon does not have the same mechanical properties as the original structure (less elasticity although stronger)

F. Tendon lacerations
1. Causes and signalment: Caused by trauma; occurs at any age
2. Clinical signs
 a. In complete transections, the stance of the horse will be altered, depending on the tendons that are affected. Unusual to have only one tendon affected and a combination of the following is usually observed
 (1) Transection of the superficial digital flexor tendon will result in slight sinking of the fetlock joint during weight bearing
 (2) Transection of the deep digital flexor tendon will result in elevation of the toe during weight bearing, secondary to unopposed pull of the extensor tendon
 (3) Transection of the suspensory ligament (either the suspensory ligament, sesamoid bones, or sesamoidean ligaments) will result in the fetlock dropping to the ground, and the horse will bear weight on the palmar-plantar aspect of its first and second phalanxes
 b. Lameness is usually immediately apparent and can vary in severity

c. An external wound is often present, but due to movement of the skin and tendons during weight bearing, the lacerated tendons may have retracted away from the skin wound

3. Diagnosis
 a. Based on position of limb and hoof during weight bearing. Also the presence of an external wound will necessitate further wound exploration
 b. Ultrasound can be performed, but is often unnecessary
4. Treatment
 a. Identify involvement of other structures (joints, tendon sheaths, other ligaments/tendons); control hemorrhage
 b. Appropriate wound care; immobilize injured region with a Robert Jones bandage with or without splint or Kimzey leg saver (for a suspensory breakdown), or apply a cast. Strict stall rest until controlled exercise can begin (usually 4-6 months after injury). Tenorrhaphy can reduce the gap between the ends of tendon, but will not keep them apposed when weight bearing
5. Prognosis and Complications
 a. Prognosis is guarded for soundness with transection of flexor tendons or suspensory ligament; extensor tendon transactions heal well, though gait deficit can remain. Prognosis is influenced by concurrent injuries. Incomplete lacerations have a fair prognosis if immobilized and managed to prevent further damage
 b. Complications: High risk of adhesion formation, wound infections, and reinjury, resulting in chronic lameness; decreased weight bearing of the injured limb can lead to overload injury of the contralateral limb such as laminitis or suspensory breakdown

VII. Diseases of muscles resulting in lameness or altered gait

A. Fibrotic myopathy
 1. Causes and signalment: Unilateral, in hindlimbs; due to fibrosis or scar tissue formation, secondary to local trauma, within the caudal muscles of the thigh (usually semitendinosis)
 2. Clinical signs
 a. Shortened cranial phase of the stride of the affected hindlimb
 b. Scar tissue restricts forward motion of limb, resulting in rapid caudal movement of hoof immediately prior to foot placement (the foot slaps hard onto the ground)
 3. Diagnosis: Unique gait
 4. Treatment: No effective medical therapy; surgical resection, or transection of scar tissue can be performed standing using local anesthesia
 5. Prognosis and complications: Scar tissue can reform; prognosis for complete resolution is poor

B. Stringhalt
 1. Causes and signalment: Two forms, idiopathic and Australian (secondary to ingestion of *Hypochoeris radica*). Usually occurs in adult horses; usually unilateral (idiopathic form)
 2. Clinical signs
 a. Affected horses have a characteristic involuntary or exaggerated flexion of one or both hindlimbs, which can be severe enough to strike their flank
 b. Can occur when they start to walk or is evident frequently during a particular gait (usually the walk)
 3. Diagnosis: Characteristic gait; Australian form in New Zealand and Australia and linked to the presence of the flatweed, *Hypochoeris radica*, on the pasture
 4. Treatment: Lateral digital extensor tenectomy and myectomy can be performed standing; remove horses from pasture with *Hypochoeris radica*
 5. Prognosis and complications
 a. Surgical tenectomy and myectomy can help; results are unpredictable
 b. Australian form will often resolve spontaneously, but can take months

C. Disruption of the reciprocal apparatus in the hindlimb
 1. Causes and signalment
 a. Peroneus tertius and superficial digital flexor muscles form the reciprocal apparatus and are tendinous bands in this region; these bands ensure that as the stifle flexes or extends, so does the hock
 b. Caused by trauma to either of these muscles; all ages affected. Avulsions of origin or insertion of peroneus tertius can occur, usually in younger horses
 2. Clinical signs: Stifle and tarsus can be moved independently (tarsus can be extended while stifle is flexed); a dimple is noted in the common calcaneal tendon when the hock is extended and the stifle is flexed
 3. Diagnosis: Ability to move stifle and hock independently of each other; pain and swelling (often over dorsal distal tibia). Radiographs for avulsion fractures
 4. Treatment: Strict stall rest to allow fibrosis of the injured tissue; after 3 months of rest, the horse can be gradually returned to exercise
 5. Prognosis and complications: Some residual gait abnormality may remain, but these horses will usually become sound; avulsion fractures have a poorer prognosis for soundness

VIII. Musculoskeletal infections: Septic arthritis, tenosynovitis

A. Etiology and signalment: Affects all ages; in neonates, secondary to hematogenous spread from distant sites (respiratory, GI tract, or umbilicus). In adults, secondary to penetrating injury or iatrogenic following joint injections or surgical procedures

B. Clinical signs: Acute onset of severe lameness (grade 4-5/5); might not be as severe if joint-sheath can drain; swelling and effusion, fever (more often seen in foals)

C. Diagnosis
1. Based on clinical signs with or without evidence of an external wound or sepsis
2. Synovial fluid analysis: Elevated total protein (greater than 4.0 g/dL), WBC (greater than 25×10^3 cells/dL), neutrophil count (greater than 80%), and presence of bacteria
3. Radiographs may identify secondary changes to adjacent structures such as osteomyelitis; often a sign of chronicity

D. Treatment
1. Obtain synovial fluid for culture prior to initiating antibiotic therapy
2. Joint lavage is vital; use copious volumes of sterile, isotonic fluid
3. Antibiotics: Administered intra-articularly (very effective), via regional limb IV perfusion or intraosseus perfusion (very effective), or systemically (less effective) bactericidal antibiotics should be used. Aminoglycosides are a first choice; gram-positive coverage with penicillin or ceftiofur
4. If osteomyelitis-osteitis or septic physitis (in foals) is identified, surgical debridement is indicated in combination with regional limb IV perfusion
5. Analgesics/antiinflammatories: NSAIDs can be used, but care should be taken in foals to limit the risk of gastric ulceration or of nephrotoxicity
6. Wound care and debridement if associated with external injury

E. Prognosis and complications
1. With aggressive therapy, resolution of the infection is possible and the prognosis for life is good. The prognosis for athletic soundness is fair
2. If infection does not resolve rapidly, there may be problems associated with overloading the contralateral limb such as laminitis (restricted to adults)

IX. Developmental orthopedic disease

A. Angular limb deformities (ALD)
1. Causes and signalment
a. Neonates: Secondary to laxity or flaccidity of periarticular structures, incomplete ossification of cuboidal bones (in the carpus or tarsus), excessive growth, or trauma to physis. Dysmaturity or prematurity can cause some of these abnormalities
b. In adults: Secondary to injury that caused severe lameness. ALD is an overload injury that occurs in the contralateral limb
c. Affects either front or rear limbs; common sites are carpus, tarsus, and fetlocks
d. Valgus (limb distal to deformity deviates laterally) or varus (limb distal to deformity deviates medially); named after the joint they affect
2. Clinical signs: Limb is not vertically aligned when viewed from the front; abnormal gait with or without lameness
3. Diagnosis
a. Inspection of the foal; affected limb(s) will deviate from a plumb line dropped from the point of the shoulder or tuber ischii
b. Radiographs: Include affected joint and long bones proximal and distal. An anteroposterior (AP) view identifies the origin (physis, joint, or incompletely ossified cuboidal bones) and angle of deviation. A lateromedial radiograph identifies collapse or damage to the cuboidal bones
4. Treatment
a. Mild deformities (less than 10 degrees), with no other radiographic abnormalities can be treated conservatively, with stall rest for 4 to 6 weeks
b. More severe deformities (more than 15 degrees) or following conservative therapy with no improvement may require surgical therapy. Either periosteal transection and elevation (periosteal stripping) is performed to accelerate growth on the concave side of the limb or a transphyseal bridge is performed to retard growth on the convex side of the limb
c. If incomplete ossification of the cuboidal bones is identified, strict stall rest must be enforced until bones have ossified. May require tube casting or be maintained either in sternal or lateral recumbency to prevent further damage to the bone
d. Hoof trimming or application of extension shoes to try and correct the position of the limb; done with caution as it can place excess stress on other joints
5. Prognosis and complications
a. Most will respond to treatment; severe ones may not resolve completely. Fetlock deformities need to be treated surgically earlier than the carpus or tarsus due to their growth plate closing at an earlier age (roughly 8 weeks of age vs. 16 weeks for the tibia)
b. Any crush injury to incompletely ossified cuboidal bones will result in a permanent deformity and predispose the joint to OA
c. Horses treated with a transphyseal bridge need to be monitored closely so that implant removal can be performed prior to overcorrection

B. Flexural limb deformities
1. Causes and signalment
a. Young, growing horses; neonates most commonly affected, but horses up to 1 to 2 years of age can develop acquired flexural deformities
b. Congenital (secondary to ingestion of locoweed or infection with influenza of the mare) or acquired (secondary to trauma, pain in the limb leading to disuse, excessive feeding, or mineral imbalance) and usually are seen as hyperflexion of the limb

c. Limb is deviated in a sagittal plane, resulting in persistent hyperflexion (also known as contracted tendons) or hyperextension of a joint
d. The distal interphalangeal, metacarpophalangeal-tarsophalangeal, carpal, or rarely the tarsal joints can be affected

2. Clinical signs
a. Hyperextension often is seen immediately after birth and the foal will have hyperextended carpi or fetlocks and be weight bearing on the palmar-plantar aspect of their pasterns
b. Hyperflexion or flexural deformities are associated with abnormal degrees of persistent flexion of the affected joint, to the degree that the limb may buckle forward when weight bearing

3. Diagnosis
a. Visual examination of the profile of the limb. Manipulation of the limb is important to see if a normal range of motion is possible; helps identify horses most likely to respond well to therapy
b. Acquired deformities secondary to another problem; with lameness, source must be identified and treated for best chance of resolution
c. Radiographs: Eliminate other lesions or injuries as cause of deformity

4. Treatment
a. Hyperextension deformities: Usually resolve within 2 to 3 days after birth by restricting ability to exercise (stall or small paddock confinement). Exercise is important to promote muscle tone, overexercising should be avoided as fatigue exacerbates hyperextension. Only use light bandages to prevent excoriations of the palmar-plantar fetlock region as these bandages can contribute to joint laxity. Heel extensions can be applied to prevent the fetlock from sinking
b. Flexural deformities can be treated by applying heavy support bandages with or without splint material for 24 hours. This promotes relaxation when the bandages are removed but may need to be repeated
c. Toe or heel extensions can be applied, depending on location (distal interphalangeal joint or metacarpophalangeal joint, respectively)
d. Rapidly growing foals may need to have feed intake reduced. If still nursing, restricting mare's concentrate intake will reduce milk production
e. Treat severe flexural deformities with IV oxytetracycline (3 g in 250 mL of saline); administer once daily for two or three treatments
f. Identify underlying cause in acquired flexural deformities; more likely to require surgery, either inferior check ligament desmotomy (for flexural deformity of the distal interphalangeal joint) or superior check ligament desmotomy (for flexural deformity of metacarpophalangeal joint)
g. Surgical therapy for flexural deformities of the carpus and tarsus require transection of the tendons that are responsible for the restricted motion

5. Prognosis and complications
a. Most hyperextension deformities resolve with minimal intervention
b. Most flexural deformities will resolve with conservative therapy, although prolonged bandaging and splinting can result in bandage sores
c. Surgical complications tend to be minor, but contraction of other periarticular structures can limit the improvement seen following surgical procedures

C. Osteochondrosis
1. Causes and signalment
a. Failure of endochondral ossification, resulting in excessively thickened regions of cartilage. Cartilage regions are damaged when mechanical forces are applied; leads to either fragmentation of the cartilage, the formation of a cartilage flap or a subchondral cyst
b. Disease of young horses; clinical signs may not be seen until the horse begins to work
c. Certain predisposing factors have been identified:
(1) Genetics: Progeny of certain stallions
(2) Nutrition and growth rate: Foals on high levels of nutrition (higher energy intake) that have rapid growth rates
(3) Mineral and trace elements: Diets deficient in copper or with excessive zinc or phosphorous levels
d. Lesions are consistently found in the following:
(1) Tibiotarsal joint: Distal intermediate ridge of the tibia, medial or lateral trochlear ridges, medial or lateral malleolli
(2) Stifle joint: Medial or lateral trochlear ridge, intertrochlear groove, patella, medial condyle of femur (subchondral bone cyst)
(3) Metacarpophalangeal-tarsophalangeal joints: Dorsally on sagittal ridge, proximal dorsal aspect of first phalanx (may be traumatic), proximal palmar-plantar aspect of the first phalanx
(4) Scapulohumeral joint: Humeral head, glenoid cavity

2. Clinical signs: Joint effusion (may be bilateral; evaluate contralateral limb); lameness (mild to severe; often observed after exercise)
3. Diagnosis: Clinical signs, age; radiographic evidence of fragmentation, an irregular articular surface or osteochondral flap, or a defect in the subchondral bone (includes cysts)

4. Treatment
 a. Conservative therapy is used where minimal lameness and joint effusion is present; reduce energy intake, restrict exercise, provide analgesics and joint therapies (intra-articular medications, systemic joint protectants like hyaluronic acid, chondroitin, etc.)
 b. Arthroscopic debridement recommended, unless osteoarthritic changes are present; least invasive method to remove unhealthy cartilage and diseased subchondral bone
5. Prognosis and complications
 a. Tibiotarsal and metacarpophalangeal lesions: Good prognosis for athletic soundness; stifle lesions have a fair prognosis
 b. Shoulder lesions: Poor prognosis and athletic soundness is unlikely

D. Physitis
1. Causes and signalment: Rapidly growing, young horses; may have traumatic component related to overload or excessive stress placed on medial aspect of limb
2. Clinical signs: Lameness (sometimes all four limbs); painful, firm swelling over the affected physis (distal 3rd metacarpal-tarsal, distal radius, and distal tibia are sites most frequently involved)
3. Diagnosis: Clinical signs and palpation; radiographs usually reveal widening and an irregular outline of the physis, often medially. The distal metaphysis will often have evidence of flaring and soft tissue swelling is usually appreciable
4. Treatment
 a. Decrease the energy content of the feed by removing any concentrate from the foal's ration, or if still nursing, remove the mare's concentrate to decrease her milk production and its energy content. This will slow the growth rate and may lead to some weight loss
 b. Strict stall rest until the physis is no longer painful and horse is sound
 c. Analgesics such as phenylbutazone
5. Prognosis and complications. Good if no severe angular or flexural deformities develop secondarily to the physitis

X. Diseases of the foot (3rd phalanx and navicular bone) and hoof

A. Thrush
1. Causes and signalment: Infectious condition, which attacks the hoof wall and the sole, particularly in the frog region; bacterial or fungal. Affects horses maintained in wet stalls or paddocks
2. Clinical signs: Foul smelling, moist, black, slimy discharge found in the sulci of the frog; sulci and the frog become softer. Lameness only if infection reaches deeper, sensitive structures
3. Diagnosis is based on clinical signs
4. Treatment
 a. Improve foot hygiene, pick feet frequently to remove debris; debride abnormal sole or hoof wall
 b. Keep stalls as *clean and dry* as possible
 c. Topical therapy with antifungal-antibacterial medication (i.e., weak povidone iodine solution soaked gauzes held in place with a foot bandage)
5. Prognosis and complications: Often recurs; good stall hygiene is best way to limit the occurrence; keep horses out of wetter paddocks or pastures

B. White-line disease
1. Causes and signalment: Usually limited to horses in wetter, humid regions; infectious component (fungal or bacterial)
2. Clinical signs
 a. An abnormal space develops between the hoof capsule and the rest of the foot, as the white line deteriorates, leaving a space between the hoof capsule and the deeper structures of the foot
 b. Crumbly or powdery horn exists in the space
 c. Lameness can be present
 d. Lateral radiographs of the hoof will usually allow identification of a gas opacity between the hoof wall and the 3rd phalanx
3. Diagnosis
 a. Based on examination of the foot and identification of the separation between the hoof capsule and the rest of the foot, filled with necrotic, powdery material
 b. Radiographs can be taken prior to therapy to identify undermined dorsal hoof wall
4. Treatment
 a. Aggressive debridement is necessary. All underrun hoof wall is resected until healthy white line tissue is reached. Debridement may need to be repeated every 2 to 3 weeks
 b. No topical medication is necessary; keep foot dry and exposed to air
5. Prognosis and complications: Often recurs, inadequate debridement is often responsible for recurrence and can take months before this resolves

C. Hoof cracks
1. Causes and signalment: Usually traumatic in origin; can be a complication of inadequate hoof care (feet left too long) or poor nutrition (weakened hoof wall). Only seen in horses not wearing shoes
2. Clinical signs
 a. Linear defect, usually in the proximodistal plane, in the hoof wall, usually extending proximally from the weight-bearing surface
 b. Variable lameness (depends on depth of crack, as involvement of sensitive lamina will cause marked lameness)
3. Diagnosis: Based on clinical signs, although diagnostic anesthesia may be necessary to identify involvement of sensitive lamina
4. Treatment
 a. Prevent crack from getting bigger by corrective trimming (floating damaged area) or by application of a shoe

b. Crack may need to be stabilized by wiring or filling defect with special synthetic hoof materials; this can trap infectious agents in sensitive tissues
5. Prognosis and complications: Resolve if they do not enlarge and if hoof has time to grow out; some horses are more prone because poor-quality hoof walls, so may need to have shoes on at all times

D. Hoof-wall injuries, avulsions
1. Causes and signalment: Traumatic and can affect any age of horse
2. Clinical signs: Varying lameness, depending on involvement of deeper, sensitive structures and extent of injury; varying degrees of hemorrhage (can be severe); obvious disruption of hoof wall
3. Diagnosis is based on clinical signs
4. Treatment
a. Stabilizing patient particularly if blood loss is marked
b. Resect loose hoof wall
c. Wound management and identification of involvement of deeper structures (e.g., joints, tendon sheath, navicular bursa, bones, tendons)
d. Application of special shoes to protect the injured area once granulation tissue is present
5. Prognosis and complications
a. Sepsis of either joints, navicular bursa, or tendon sheath significantly decrease the prognosis
b. Most uncomplicated hoof-wall injuries will do well; however, it can take months for hoof wall to regenerate

E. Hoof abscesses
1. Cause and signalment
a. One of the most common causes of acute, severe lameness in horses
b. Trauma or penetrating injury leads to bruising (perfect medium for bacterial growth) or direct inoculation of bacteria into deeper structures
c. Build up of pressure and purulent material leads to marked discomfort
2. Clinical signs: Acute onset of severe lameness (4-5/5). Following drainage, lameness improves; remains severe for 24 to 48 hours. Increased digital pulses
3. Diagnosis
a. When the sole or hoof wall is examined, hoof testers will reveal the most sensitive area
b. A track or defect is often identified on the solar surface and may produce foul smelling, grey-black fluid
c. Radiographs of the hoof will usually allow identification of a gas opacity between the hoof wall and the 3rd phalanx
4. Treatment
a. Establish drainage ventrally by following any abnormal tracks or defects in the hoof. Once hemorrhage is seen, little more if any resection should be performed
b. Soak affected foot to help dilute or flush out any residual infection (10 to 15 minutes in water mixed with Epsom salts or very dilute iodine solution)
c. Analgesics such as phenylbutazone
d. Keep area clean to prevent infection being trapped in the defect and limit activity until defect has healed (can take weeks if large)
5. Prognosis and complications: If the infection is resolved, the horse should recover fully. They can recur if any infection remains

F. Sole bruises
1. Causes and signalment: Trauma to the solar surface of the foot. Hemorrhage occurs in the lamina and increases the pressure, resulting in lameness
2. Clinical signs
a. Variable lameness (severe initially; often decreases after a few days)
b. Sensitivity to hoof testers over bruised region
c. If thin soled, or chronic, may see discoloration of the sole (areas of hemorrhage within the solar tissue)
d. No radiographic abnormalities
3. Diagnosis: Based on clinical signs and lack of radiographic changes or presence of abscessation
4. Treatment
a. Analgesics such as phenylbutazone
b. Exercise restriction until the lameness subsides
c. Apply shoes to limit sole contact with the ground or use a shoe with a sole pad
5. Prognosis and complications: Good; horses with thin soles prone to recurrence

G. Third phalanx fractures
1. Causes and signalment: Occur at any age; usually traumatic
2. Clinical signs: Severe lameness (4-5/5); increased digital pulses and heat within hoof
3. Diagnosis: Application of hoof testers will reveal generalized, often profound, sensitivity; radiographs will confirm fracture type. May need multiple views
4. Treatment
a. Stall rest is important
b. If small fragment, some can be removed. Sagittal fractures can be repaired using cortical screws placed in lag technique
c. Application of a full rim shoe to limit hoof expansion until fracture heals
5. Prognosis and complications
a. Variable depending on age, type of fracture, and if there is an articular component
b. Secondary changes such as OA reduce the prognosis
c. Healing can be prolonged or incomplete leading to a nonunion

H. Navicular disease (caudal heel pain)
1. Causes and signalment
 a. This condition is usually seen in older horses that are in work; most common in quarter horses, thoroughbreds, and warmbloods
 b. Caudal heel pain is a more accurate description; source of the lameness often originates from a structure other than the navicular bone and can be associated with any of the ligaments that support the bone, the deep digital flexor tendon, or navicular bursa
2. Clinical signs
 a. Bilateral, progressive forelimb lameness (often one limb is more severely affected)
 b. Affected horses will often have relatively small feet compared with their body weight (particularly quarter horses)
 c. Often insidious onset of lameness
3. Diagnosis
 a. Hoof testers will reveal sensitivity over frog and heel region
 b. Lameness isolated to distal limb, usually after a palmar digital nerve block, and will then often reveal contralateral forelimb lameness
 c. Radiographs may reveal changes in the navicular bone, but if the soft tissues are the source of the lameness, changes will not be apparent. Radiographic changes associated with navicular disease include increased number and size of synovial fossae on the distal border of the navicular bone; medullary lucencies or sclerosis compared with cortex; entheseophyte or osteophyte formation along the navicular bone's borders; irregularity of the articular surface
 d. MRI will allow identification of injuries in the supporting structures
4. Treatment
 a. Analgesics such as phenylbutazone
 b. Corrective trimming and shoeing. Correcting any hoof imbalances is vital. Benefit from increased support to their heels and slight elevation (e.g., a bar shoe with a wedge)
 c. Intra-articular medication such as steroids or hyaluronic acid into either the distal interphalangeal joint or the navicular bursa
 d. Palmar digital neurectomy to prevent feeling pain from this area
5. Prognosis and complications
 a. Poor prognosis: With careful management, the horse can often be used for 1 or 2 years or longer, but the disease usually will progress
 b. Complications include rupture of the deep digital flexor tendon, luxation of the distal interphalangeal joint, severe hoof abscessation (unable to feel pain to display clinical signs), neuroma formation, failure to alleviate lameness

I. Laminitis
1. Causes and signalment
 a. Usually affects forelimbs but can involve the hindlimbs (especially in systemically sick patients)
 b. Can occur following any septic process (e.g., colitis, metritis, strangulating forms of colic), excess ingestion of grain or lush pasture, limb overload secondary to orthopedic disease of the contralateral limb or Cushing disease
 c. The laminar tissue connecting the hoof capsule to the 3rd phalanx begins to break down and stretch, resulting in extreme pain and potentially, displacement of the 3rd phalanx in relation to the hoof capsule
2. Clinical signs: Severe lameness (4-5/5), unwilling to move or even stand in extreme cases; can affect one to four hooves; bounding digital pulses; extremely uncomfortable with decreased appetite
3. Diagnosis
 a. Based on clinical signs
 b. Identification of another condition (or one in the history) such as metritis or colitis that can lead to laminitis
 c. Generalized sensitivity to application of hoof testers but often more pronounced cranial to apex of frog
 d. Lateral radiographs of the feet can either be normal, or in more severe cases can reveal: Rotation of the 3rd phalanx away from the dorsal hoof wall and distal displacement or sinking (moves distally, even further below the coronary band than normal) of the 3rd phalanx
4. Treatment
 a. Immediate stall rest in a well-bedded stall
 b. Dietary restrictions (stop feeding fresh grass, grain, or concentrate immediately and replace with grass hay only)
 c. Analgesics such as phenylbutazone. Stronger drugs may be needed, but should be used with caution (detomidine, butorphanol)
 d. Vasodilators such as acepromazine or vasoconstrictors such as applying ice to the feet (pathophysiology of laminitis remains unclear, hence paradoxical therapies)
 e. Applying frog supports to the horse's feet (either frog-support material, high-density foam, polystyrene pads, or rolled gauze)
 f. If severe rotation of the 3rd phalanx has occurred (i.e., more than 15 degrees), a deep digital flexor tenotomy can be performed to attempt to limit its progression
 g. Following the initial acute phase, when the horse is no longer as lame, corrective trimming and shoeing combined with continued rest is necessary to allow the lamina to heal; takes months and the horse will remain at risk for a further laminitic episode for the remainder of its life

5. Prognosis and complications
 a. Prognosis for soundness is poor. Ponies have a slightly better prognosis because of their smaller size
 b. Likely to recur
 c. Presence of rotation of the 3rd phalanx greater than 15 degrees, sinking of the 3rd phalanx or penetration of the 3rd phalanx through the sole; prognosis is grave

XI. Diseases of the 1st and 2nd phalanx and the proximal interphalangeal joint
 A. Fractures of the 2nd phalanx
 1. Causes and signalment: Caused by trauma; affect all ages
 2. Clinical signs: Acute onset, severe lameness, palpable crepitus upon manipulation of the limb; pain and swelling associated with the fracture, varying degree of limb instability, depending on fracture configuration
 3. Diagnosis: Clinical signs, radiographs to confirm
 4. Treatment
 a. Palmar-plantar eminence fractures can sometimes be repaired
 b. Most require surgical repair and usually pastern joint arthrodesis
 c. Comminuted fractures may need to be treated with placement of a half limb cast with transfixation pins through the cannon bone
 5. Prognosis and complications
 a. Simple fractures or those involving the palmar-plantar eminences have a fair prognosis for soundness following surgical repair
 b. Comminuted fractures have a grave prognosis for soundness
 c. Biarticular (fracture spans from proximal articular surface to the distal articular surface) fractures have an even worse prognosis for soundness
 d. Contralateral limb laminitis or complications of the fractured limb such as implant infection or failure; cast sores or local infection
 B. OA of the proximal interphalangeal joint. See OA section. This joint can be arthrodesed and still produce a horse that is sound
 C. Osteochondrosis of the 1st phalanx
 1. Proximal dorsal fractures: Either osteochondrosis lesions or caused by trauma
 2. Osteochondrosis lesions do occur on the proximal palmar/plantar aspect
 3. Lameness, joint effusion; require arthroscopic removal
 D. Fractures of the 1st phalanx
 1. Causes and signalment: Dorsal frontal fractures occur only in racehorses. Diaphyseal fractures are traumatic in origin
 2. Clinical signs: Acute onset, severe lameness; pain upon manipulation
 3. Diagnosis: Radiographs are essential
 4. Treatment
 a. Dorsal frontal fractures can be treated with rest or surgical repair
 b. Diaphyseal fractures require surgical repair; may need either pastern or fetlock arthrodesis to allow appropriate reconstruction of the bone
 c. Application of a transfixation cast in severely comminuted fractures
 5. Prognosis and complications
 a. Dorsal frontal fractures have a good prognosis following surgical repair
 b. Other types have a guarded prognosis due to prolonged convalescence and risk of contralateral limb complications (laminitis)

XII. Metacarpo-tarsophalangeal (fetlock) joint
 A. OA of the fetlock joints. See OA section
 1. More common in racehorses than in other performance horses
 2. Joint can be arthrodesed; horse can be bred but not ridden or competed
 B. Osteochondrosis of the fetlock joint
 1. As well as proximal fragments from the 1st phalanx, the sagittal ridge of the distal 3rd metacarpal-tarsal bone can be affected
 2. Arthroscopic debridement is recommended
 C. Chronic proliferative (villonodular) synovitis
 1. Causes and signalment: Only in racehorses. Repeated overextension of the fetlock joint results in trauma to normal synovial plica in dorsal recess of the joint. This responds by fibrosis and enlarges
 2. Clinical signs: Palpable soft tissue swelling over the dorsal aspect of the fetlock joint, forelimb lameness
 3. Diagnosis: Lameness isolated to fetlock; radiographs show marked soft tissue swelling, with depression of 3rd metacarpal bone proximal to the sagittal ridge
 4. Treatment: Arthroscopic resection of proliferative plica will usually allow the horse to return to racing
 5. Prognosis and complications. Presence of OA decreases prognosis

XIII. Proximal sesamoid bones
 A. Sesamoiditis
 1. Causes and signalment: Usually seen in racehorses. Related to bone remodeling as a result of forces applied to it and the rest of the suspensory apparatus during training
 2. Clinical signs: Pain on palpation or flexion of fetlock; lameness may be mild unless the horse has been recently worked
 3. Diagnosis
 a. Lameness will usually improve following nerve blocks, but not intra-articular anesthesia of the fetlock
 b. Radiographic changes associated with sesamoiditis include osteophytes and enthesiophytes, enlargement of vascular channels, focal osteolysis

4. Treatment: Prolonged rest; analgesics (phenylbutazone) and topical antiinflammatory therapy (e.g., cold hosing, icing, poultices)
5. Prognosis and complications: Response to therapy can be poor, but older horses tend to respond better than young horses

B. Proximal sesamoid bone fractures
1. Causes and signalment
 a. Most common in racehorses; can occur in all ages used for any purpose
 b. With race training, the suspensory ligament strengthens, meaning that hyperextension of the fetlock often leads to sesamoid fracture rather than rupture of the suspensory ligament (in non-racehorses, the bone is usually stronger than the suspensory ligament)
 c. Different fracture configurations exist and have different prognoses
2. Clinical signs
 a. Lameness becomes severe following work; soft tissue swelling over sesamoid region, pain on palpation
 b. If both sesamoid bones are fractured, the fetlock will lose all support; unable to maintain fetlock in extension and will be non–weight bearing
3. Diagnosis
 a. Radiographs will identify the fracture configuration: Apical, mid-body, basilar, axial, or abaxial
 b. Ultrasound should be performed to assess the integrity of the suspensory ligament as this is more important prognostically for abaxial and apical fractures
4. Treatment
 a. Removal of the fragments is recommended for apical, abaxial, and basilar fragments
 b. Surgical reconstruction should be attempted for mid-body fractures
 c. Conservative therapy is the only option for axial fractures; can be used for small apical or abaxial fragments
 d. Fetlock arthrodesis: Only option for fractures of both sesamoid bones
5. Prognosis and complications
 a. Concurrent suspensory ligament desmitis decreases prognosis
 b. Mid-body, basilar and axial fractures have a poor/guarded prognosis

XIV. 3rd metacarpal/tarsal (cannon) bone

A. Condylar fractures
1. Causes and signalment
 a. Occur exclusively in racehorses and are either laterally or medially (medial more common in the hindlimb in thoroughbreds)
 b. Because of remodeling occurring in the distal portion of the 3rd metacarpal-tarsal bone; remodeling is secondary to forces applied during training or racing and as bone mineralizes, it is prone to development of microfractures, which propagate into condylar fractures
 c. Fractures are complete or incomplete (does not break out of the cortex), spiral (tends to be medial condylar fractures), displaced, or nondisplaced
2. Clinical signs: Acute onset of severe lameness following fast work; pain on manipulation of fetlock joint; swelling
3. Diagnosis: Clinical signs; radiographs confirm and identify fracture configuration
4. Treatment
 a. Incomplete, nondisplaced condylar fractures treated conservatively with stall confinement and application of heavy bandage for 3 to 4 months
 b. All complete, spiral, or displaced condylar fractures must be repaired surgically by placement of bone screws using lag technique or application of plates and screws for certain spiral fractures
 c. Surgical treatment will give the most rapid return to training or racing and is recommended for the majority of cases
5. Prognosis and complications
 a. The damage that occurs when theses horses fracture their limbs leads to the development of OA
 b. Lateral condylar fractures tend to have a favorable prognosis following surgical repair
 c. Medial condylar fractures, or fractures that are complete, displaced, or that have a spiral component all have a poorer prognosis for a return to racing
 d. Horses with a medial condylar fracture must have their entire cannon bone evaluated radiographically to ensure that a spiral component is not present, as this can lead to catastrophic fracture during recovery from anesthesia or even weeks later when confined to a stall
 e. The presence of an axial sesamoid fracture or comminution of the articular surface also reduces the prognosis for a successful return to racing

B. Bucked shins (dorsal metacarpal diseases)
1. Causes and signalment: In racehorses (usually 2- to 3-year-olds); secondary to multiple minor cortical fractures in dorsal aspect of the 3rd metacarpal bone (rarely in 3rd metatarsal bone). Training and racing yield huge amounts of stress on the dorsal cortex of the cannon bone. Attempts to remodel to withstand forces; microfractures occur if training continues before bone is strong enough
2. Clinical signs: Lameness, usually forelimbs; lame following exercise, decreased performance. Excessive pain on light palpation of dorsal aspect of 3rd metacarpal bone (usually dorsomedial aspect)
3. Diagnosis: Clinical signs; radiographs reveal periosteal reaction, which is useful prognostically. Multiple views to allow good visualization. Actual fractures are not commonly seen in this stage of the condition

4. Treatment
 a. Decrease level of training if lameness is mild; many need to be rested, sometimes for months, to allow bone remodeling and healing
 b. Analgesics (phenylbutazone): Can continue to train if lameness is mild
 c. Local therapy such as cold hosing or icing the limbs
5. Prognosis and complications
 a. Depends on degree of periosteal reaction. If excessive, more time is required for bone to remodel and will limit future athletic soundness
 b. If horses continue to race or train, despite having bucked shins, dorsal cortical fractures or saucer fractures can occur

C. Dorsal cortical fractures
1. Causes and signalment
 a. Usually course dorsally and proximally from interior portion of cortex
 b. Sequelae to bucked shins. If horses are returned to training without appropriate rest, the remodeling and sclerotic bone may sustain a unicortical fracture
 c. Severe dorsal cortical fractures can progress and form saucer fractures, which affect a larger portion of the bone and may form a sequestrum
2. Clinical signs
 a. Lameness, usually forelimbs. Horses will usually be consistently lame, unlike with bucked shins
 b. Excessive pain upon light palpation of dorsal aspect 3rd metacarpal bone (usually dorsomedial aspect)
 c. Swelling often palpable due to soft tissue and periosteal reaction
3. Diagnosis
 a. History of bucked shins
 b. More marked lameness than previously
 c. Radiographs will allow identification of fracture lines. Fractures usually course proximally, at a 30- to 40-degree angle, although they can be at any angle. In saucer fractures, this fracture line will remain within the cortex but as it heads proximally, it curves to exit the cortex again
4. Treatment
 a. Conservative: Can rest horse for prolonged period and monitor healing radiographically
 b. Surgical: Osteostixis can be performed to drill multiple holes through and around the fracture line to attempt to stimulate healing, or a unicortical screw can be placed through the fracture
5. Prognosis and complications
 a. Surgical therapy tends to produce a better outcome; if adequate rest is given, these horses have a good prognosis to return to racing
 b. Conservative therapy can require prolonged periods of rest and fractures will sometimes not heal despite prolonged rest
 c. Gradually return to training to prevent further stress related injury

XV. Other 3rd metacarpal-tarsal fractures
A. Diaphyseal and metaphyseal fractures occur secondary to trauma
B. These injuries require internal fixation and are frequently open and comminuted
C. Adult horses have a poor prognosis; smaller horses can survive if appropriate therapy is initiated. Prognosis varies depending on the degree of comminution, the fragment sizes, and proximity to or involvement of joints

XVI. 2nd and 4th metacarpal and metatarsal bones
A. Splint exostoses (splints)
1. Causes and signalment
 a. Usually seen in younger horses but can occur in older horses
 b. Thought to be traumatic but may be caused by instability between the splint bone and the cannon bone. Usually in proximal third of cannon bone
2. Clinical signs: Firm swelling of splint bone; pain and lameness in acute stage (but not in chronic stage)
3. Diagnosis: Palpation, clinical signs; radiographs and ultrasound can identify impingement on suspensory ligament
4. Treatment: Rest until tenderness and lameness resolves (usually short period); surgical amputation or resection if impinging on the suspensory ligament or for aesthetic reasons
5. Prognosis and complications
 a. Prognosis is good for a return to soundness once the lameness subsides
 b. If the exostosis places pressure on the suspensory ligament, it can cause suspensory desmitis and lead to chronic lameness

B. Fractured splint bones
1. Causes and signalment
 a. Usually traumatic. The lateral splint bone is most commonly injured
 b. Can occur secondarily to severe suspensory ligament desmitis (ligament becomes enlarged and places pressure on the bone)
2. Clinical signs: Lameness; open wound over injury; pain, crepitus, swelling
3. Diagnosis. Radiographs will reveal the extent of the fracture
4. Treatment: Surgically remove fractured bone with distal and midbody fractures. Repair proximal splint bones with internal fixation (provides stability to tarsal and carpal joints); can remove 4th metatarsal bone
5. Prognosis and complications
 a. Return to full soundness if articular surface is not destabilized
 b. Fractures secondary to suspensory ligament desmitis have a poorer prognosis (related to the ligamentous injury rather than the fracture)

XVII. Carpus
- A. OA of the carpus
 1. Affects any of the three carpal joints: Radiocarpal, middle carpal, or carpometacarpal joint
 2. Usually seen in horses that have had racing careers
 3. Clinical signs, diagnosis, and treatment descriptions found in the OA section
 4. Carpal arthrodesis is an option; results in permanent lameness from loss of flexion in high motion joints
- B. Osteochondral fragments
 1. Causes and signalment
 a. Traumatic in origin; usually restricted to racing horses
 b. Arise from distal radius, proximal radial or intermediate, distal radial or intermediate, and proximal 3rd carpal bones
 2. Clinical signs: Lameness, carpal effusion, pain with passive flexion of carpus
 3. Diagnosis. Radiographs will identify presence and location of fragments. Contralateral carpus should be evaluated at the same time
 4. Treatment
 a. Arthroscopic removal; allows accurate evaluation of articular cartilage and ligaments within joint
 b. Conservative therapy with intra-articular injections will allow horse to continue racing but not always at the same level of competition
 5. Prognosis and complications
 a. Conservative therapy allows horse to continue to race; further damage to the joint occurs from chronic synovitis and irritation from the chip
 b. Arthroscopic removal provides the best prognosis for a return to racing. Concurrent damage to the carpal ligaments or severe cartilage damage can reduce the prognosis for soundness
- C. 3rd carpal slab fractures
 1. Causes and signalment
 a. Almost exclusively in racehorses
 b. Usually occur in frontal plane of the 3rd carpal bone; the result of stress adaptive remodeling and repetitive trauma during training or racing
 c. Fracture extends from middle carpal joint to carpometacarpal joint
 2. Clinical signs: Marked lameness, carpal effusion, pain on flexion of carpus
 3. Diagnosis: Radiographs, including skyline view of distal row of carpal bones. Contralateral carpus should be evaluated at the same time
 4. Treatment: Surgical repair; internal fixation with arthroscopic guidance, if fracture fragment is thick enough (>8mm) to hold a cortical screw; otherwise remove fragment. Conservative therapy if the fragment is nondisplaced
 5. Prognosis and complications
 a. Surgical repair: Best prognosis for return to racing; horses often unable to return to the same level of competition
 b. Conservative therapy can take prolonged periods of rest and will hasten the onset of severe OA. These horses have a poorer prognosis

XVIII. Radius and ulna
- A. Radial fractures
 1. Causes and signalment: Severe trauma (bad fall or kick); any age affected
 2. Clinical signs: Severe lameness, usually non–weight bearing; severe soft tissue swelling with or without crepitus. Fractures are often open because of lack of soft tissue coverage
 3. Diagnosis: Clinical signs, presence of open fracture, radiographs
 4. Treatment: Prompt first aid (see previous section); internal fixation necessary
 5. Prognosis and complications
 a. Horses weighing more than 250 kg have a grave prognosis; those less than 250 kg have better prognosis for successful therapy but still require internal fixation
 b. Incomplete or nondisplaced fractures treated with stall rest; can become complete or displaced at any time, necessitating euthanasia or more aggressive treatment
- B. Ulna fractures
 1. Causes and signalment
 a. Traumatic in origin, usually secondary to a kick injury
 b. Triceps inserts on the olecranon; fracture of the ulna disrupts ability to maintain elbow joint in extension; prevents weight bearing
 2. Clinical signs: Non–weight-bearing lameness with a dropped elbow, crepitus over caudal aspect of antebrachium
 3. Diagnosis: Radiographs will identify the fracture configuration and any articular component
 4. Treatment: Internal fixation using a dynamic compression plate; conservative therapy (stall rest; application of a Robert Jones bandage and dorsal splint)
 5. Prognosis and complications
 a. Surgical repair gives a good prognosis as long as the articular surface can be reconstructed
 b. Conservative therapy leads to prolonged healing times and often results in secondary complications such as angular limb deformities, contralateral limb laminitis, or OA

XIX. Elbow joint
- A. This joint rarely is injured, with the exception of ulna fractures
- B. OA can result if these are not treated appropriately

XX. Humerus fractures
- A. Causes and signalment: Trauma (kick or collision)
- B. Clinical signs: Non–weight-bearing lameness, swelling from point of shoulder to mid antebrachium; crepitus

C. Diagnosis: Clinical signs, exclusion of other causes of lameness. Radiographs confirm (difficult to penetrate this region with most radiograph machines)
D. Treatment: Surgical repair is usually unsuccessful in all but the smallest foals; conservative therapy with stall rest
E. Prognosis and complications
1. Adult horses have a poor prognosis, so euthanasia is often required
2. Conservative therapy will often lead to angular limb deformities or development of laminitis in the contralateral limb
3. Damage to the radial nerve can also complicate the recovery

XXI. Scapulohumeral joint (shoulder)
A. Osteochondrosis
1. Cause of lameness in young horses (i.e., less than a year of age). Lesions occur on either the humeral head or in the glenoid cavity
2. Even with treatment, OA often develops leading to chronic lameness
B. Fractures
1. Supraglenoid tubercle is origin of the biceps brachii muscle. Avulsion fractures require surgical fixation with screws, fragment removal, or conservative therapy
2. The scapula can fracture in other locations, and surgical repair is difficult due to the relatively thin bone
C. Suprascapular nerve injury (Sweeney)
1. Causes and signalment: Associated with trauma to the scapula, usually the cranial edge (either a kick or running into an object)
2. Clinical signs: Abnormal lateral motion of shoulder during weight bearing associated with the loss of support because of laxity in the infraspinatus muscle
3. Diagnosis: History of trauma; abnormal motion of the shoulder is unique
4. Treatment: Prolonged rest, systemic anti-inflammatories; scapular nerve decompression by resection of the cranial edge of the scapula
5. Prognosis and complications: Good prognosis for a full recovery, but some muscle atrophy may remain

XXII. Tarsus
A. OA of the distal intertarsal and tarsometatarsal joints: Most common cause of lameness in the tarsus; intra-articular medication used to manage in most horses
B. Osteochondrosis: One of the most commonly affected joints. Arthroscopic debridement gives good prognosis for soundness, but some joint effusion may remain
C. Gastrocnemius avulsion
1. Causes and signalment: Requires severe trauma; occurs at any age
2. Clinical signs
a. Unable to fix its tarsus in extension; unable to bear weight on the limb
b. Hock will flex whenever weight bearing is attempted and hock will flex when the stifle is in extension
c. Soft tissue swelling and pain upon palpation of the gastrocnemius
3. Diagnosis: Identification of swelling over the gastrocnemius and inability to bear weight is characteristic. Ultrasound used to assess
4. Treatment
a. Younger and smaller horses can be placed in a full limb cast
b. Prevent weight bearing (place horse in sling); may prevent exacerbation of injury to allow gastrocnemius to heal; necessary for a prolonged period
5. Prognosis and complications
a. Complete avulsions or ruptures in adults: Grave prognosis; euthanize
b. If treated, overload injuries of the other three limbs are possible
c. Even with a full limb cast, enough motion remains in the tarsus that healing can be prolonged or incomplete at the time of cast removal

XXIII. Tibia: As with radial fractures, these have a tendency to become open medially owing to the lack of soft tissue coverage; in adults, surgical repair has a grave prognosis for survival

XXIV. Stifle
A. Femoropatellar, medial, and lateral femorotibial joints. The patella is attached to the limb via the patellar ligaments and the insertion of the quadriceps muscles. Cartilagenous menisci and cruciate ligaments are important structures which help to stabilize this joint
B. OA of the stifle: This is often a career-ending condition as it leads to a severe and chronic lameness that responds poorly to treatment
C. Osteochondrosis
1. Lesions most commonly in the femoropatellar joint (trochlear ridges or patella) or in the medial femorotibial joint (subchondral bone cyst of the medial condyle)
2. Best treated with arthroscopic debridement; fair prognosis for soundness
D. Trauma
1. Traumatic injuries damage the collateral ligaments, menisci, or cruciate ligaments. Results in severe lameness; diagnosed using radiographs with or without ultrasonography
2. Arthroscopic debridement helpful in meniscal or cruciate injuries and provides prognostic information. Injuries require prolonged rest; risk of reinjury or chronic lameness is high
E. Upward fixation of the patella
1. Causes and signalment: Affects younger horses (less than 3 years of age)
2. Clinical signs
a. The hindlimb is locked in extension with the fetlock joint flexed
b. Until the patella is released, the limb is unable to be flexed

c. An audible snap is often heard when the patella releases, and the animal will then usually be able to move normally again
3. Diagnosis: Abnormal degree of extension and inability to flex limb is characteristic
4. Treatment
a. Moving the horse backwards or attempting to pull the limb forward will often release the limb
b. Allow the horse to mature; improve level of conditioning
c. Turn out to pasture, as stall confinement is contraindicated
d. Analgesics such as phenylbutazone to encourage exercise
e. If conservative therapy does not work or the limb cannot be flexed, medial patellar ligament desmotomy will provide immediate relief. Medial patellar ligament splitting or injection of irritants will also help relieve clinical signs, just not as rapidly, but with fewer risks of complications
5. Prognosis and complications: Conservative therapy (usually successful with no residual lameness); most grow out of this as they get older or gain condition. Medial patellar ligament desmotomy carries risk of patellar fragmentation if not rested for an appropriate period.

XXV. Femur fractures
A. Causes and signalment: Traumatic in origin
B. Clinical signs: Severe lameness with marked soft tissue swelling; palpable crepitus. Limb may appear shorter than the contralateral limb as a result of overriding of bone fragments
C. Diagnosis: Clinical signs; radiographs (imaging the entire femur can be difficult in the standing horse)
D. Treatment: Surgical repair is necessary but difficult due to the depth of muscle coverage and curve of the bone
E. Prognosis and complications: Poor for adults; young horses and ponies have a better prognosis due to their smaller size, but fracture configuration is important

XXVI. Pelvis
A. Fracture
1. Causes and signalment: Caused by trauma; can occur at any age
2. Clinical signs
a. Results in varying degrees of lameness, depending on the amount of instability that is created. Non–weight-bearing portions of the pelvis, such as the tuber coxae tend to cause less severe lameness
b. Crepitus can be palpated when the horse's pelvis is rocked from side to side or sometimes via rectal palpation
3. Diagnosis: Palpation of crepitus is suggestive of some instability; radiographs (under general anesthesia), ultrasound, rectal palpation or transrectal ultrasound, depending on location of fracture
4. Treatment: Prolonged periods of stall confinement are required; analgesics, support the contralateral limb
5. Prognosis and complications
a. Major blood vessels and some nerves are closely associated with the pelvis; major blood loss or permanent neurologic deficits can occur
b. If the acetabulum is involved, the prognosis for soundness is grave, but fractures elsewhere have a fair prognosis for survival

B. Coxofemoral luxation
1. Uncommon; diagnosed by shortening of the affected limb, outward rotation of the distal limb, and lameness. Radiographs can confirm
2. Reduction is attempted under general anesthesia, but subsequent reluxation is likely during the recovery process. Femoral head and neck excision can be attempted in small horses or ponies

URINARY SYSTEM

I. Kidneys
A. Causes and signalment: Few surgical conditions exist that affect the kidneys. Renal or ureteral calculi and renal neoplasias are uncommon
B. Clinical signs: Vague malaise, including weight loss, anorexia, and colic; urinary signs are less common (e.g., hematuria)
C. Diagnosis: Rectal palpation or ultrasound; transabdominal ultrasound can identify renal calculi or neoplasia; renal biopsy; endoscopic exam of ureters and ureteral orifice can sometimes identify obstructions
D. Treatment: Nephrectomy if unilateral; otherwise, supportive therapy for renal failure
E. Prognosis and complications: Many potential complications associated with nephrectomies in horses. If the horse survives the surgery and the contralateral kidney is functioning normally, the horse should have a good prognosis

II. Ectopic ureters
A. Not as common as in other species
B. Horses have urinary incontinence; diagnosis by endoscopic visualization of an ectopic ureteral orifice or with radiographic contrast studies in small horses
C. Treatment involves nephrectomy if unilateral or neo-ureterostomy (relocation of ureter to more appropriate location within bladder)

III. Bladder
A. Uroperitoneum
1. Causes and signalment
a. Usually seen in neonatal foals (between 1 and 5 days old); in adults secondary to a chronic urethral obstruction or bladder rupture
b. In foals, it is traumatic in origin and either occurs during parturition or shortly after due to excessive compression of the caudal abdomen (when lifting a foal, stepped on by mare, etc)

2. Clinical signs: Normal urination is possible, but stream is usually smaller than expected; depression, anorexia, colic, abdominal distention
3. Diagnosis
 a. Clinical signs are suggestive
 b. Transabdominal ultrasound will reveal excessive, hypoechoic abdominal fluid
 c. Abdominocentesis will produce a large volume of clear, watery fluid. Drainage performed with caution until IV fluid therapy can be initiated
 d. The ratio of creatinine within the peritoneal fluid to the serum is greater than 2:1
 e. Metabolic acidosis, hyperkalemia, hyponatremia, hypochloremia, elevated BUN and creatinine
4. Treatment
 a. Fluid therapy to correct dehydration and resolve hyperkalemia (i.e., less than 5.5mEq/L) before induction of anesthesia. Treatments include: Isotonic fluids with no potassium (i.e., 0.9% saline) or dextrose solutions with or without insulin therapy (only if glucose levels are closely monitored until they stabilize, which can be hours later)
 b. Peritoneal drainage to reduce pressure on the diaphragm
 c. Cystorrhaphy (surgical repair of the ruptured or leaking bladder)
5. Prognosis and complications
 a. Foals: Complete recovery if early therapy; sepsis or other problems will decrease the prognosis for survival
 b. Adult horses: Poorer prognosis (related to underlying cause)

B. Patent urachus
1. Causes and signalment: Occurs only in neonatal foals and can be a primary condition or is usually associated with other problems, such as sepsis or following excessive straining
2. Clinical signs: Urine discharge from umbilical stump (causes scalding and inflammation); swelling, and discomfort in umbilical region
3. Diagnosis: Clinical signs; ultrasound identifies patency of urachus, contrast radiographs of draining tract
4. Treatment
 a. If no systemic illness, can attempt topical cauterizing agents applied once daily, such as chlorhexidene or Lugol's iodine
 b. If systemically ill or febrile, or cauterizing agents do not work within a week, surgical exploration and cystoplasty are indicated
5. Prognosis and complications: Good unless there is concurrent systemic illness

C. Urolithiasis
1. Causes and signalment
 a. Usually seen in older male horses, although will rarely occur in mares
 b. Two types of calcium carbonate stones are found in horses, one is softer, spiculated, green, and will adhere to the bladder wall, whereas the second type is hard, white, and smooth
2. Clinical signs: Hematuria (increased following exercise), tenesmus, urinary incontinence, dysuria, stranguria, oliguria, reduced athletic performance
3. Diagnosis: Rectal palpation of bladder, identification of stone(s); cystoscopy
4. Treatment: Surgical removal is indicated as dietary management will not dissolve this type of stone. Via a perineal urethrotomy, stone is broken up and flushed out or grasped and removed in pieces. Cystotomy via diagonal, parainguinal, or paramedian laparotomy
5. Prognosis and complications: Recurrence; examine for nephroliths, as this increases recurrence. Prognosis good if no nephroliths and removal is successful

IV. Urethral obstruction

A. Causes and signalment: Usually secondary to a urethral calculi but can occur following scarring (after a perineal urethrotomy or other urethral surgery), neoplasia, or extramural compression (hematoma)

B. Clinical signs: Colic (anorexia, abdominal pain, straining); little to no urine passed despite multiple attempts

C. Diagnosis
1. Rectal palpation of bladder distension
2. Inability to catheterize bladder or visualization of obstruction with urethroscopy
3. If bladder has ruptured, will have uroperitoneum (see earlier)
4. No evidence of endotoxemia will aid differentiation from GI disease

D. Treatment
1. The goal is to reestablish urinary outflow before bladder rupture
2. Attempt to flush obstruction back into bladder using sedation and retrograde lavage (temporary solution; urethrolith will need to be removed)
3. Divert urinary flow by a perineal urethrotomy (assuming obstruction is distal to the surgical site) and remove urethrolith by lavage or following breaking it up
4. Laparocystotomy
5. Laser resection of strictures or neoplasia (needs to be cautious as excessive damage to urethra will result in more scarring with or without urethral rupture)

E. Prognosis and complications
1. Surgery will cause discomfort, but the degree of straining should decrease as the inflammation subsides
2. Can recur if all of the debris is not removed
3. Perineal urethrotomy will result in some urine scalding of the hindlimbs initially, which will require management to prevent severe skin reactions

REPRODUCTIVE SYSTEM

I. Testicles
 A. Cryptorchidism
 1. Causes and signalment
 a. One or both testicles do not descend to lie within their normal location within the scrotum
 b. The testicle may be within the abdomen or within the inguinal canal
 c. Cause is unclear
 d. Saddlebreds and quarter horses may be overrepresented
 2. Clinical signs: One or both testicles not present in scrotum; abnormal stallion behavior in a horse that is thought to have been castrated
 3. Diagnosis
 a. Scrotal palpation usually after sedation to identify empty scrotum
 b. Human chorionic gonadotropin stimulation test to confirm presence of testicular tissue in a horse with no palpable testicles (will cause marked rise in testosterone levels)
 c. Estrone sulfate test can be performed in horses more than than 3 years of age
 d. Rectal palpation (only possible in older horses)
 e. Ultrasound examination of inguinal and scrotal region
 4. Treatment: Castration either under general anesthesia via an inguinal, parainguinal, or laparoscopic approach or standing using a laparoscopic approach
 5. Prognosis and complications
 a. Assuming both testicles are removed, horses should return to normal
 b. All undesired stallion-like behavior may not stop, as some of this is learned behavior
 c. Endocrine testing is recommended if only one testicle can be located at surgery as monorchidism, although rare, does occur
 d. Following an inguinal or, rarely, a scrotal approach, evisceration can occur. Packing the inguinal ring or suturing it or the scrotum closed are techniques to prevent this
 e. Hemorrhage is rare; minor vessels are not a concern, but hemorrhage from the spermatic cord and testicular artery needs to be controlled
 B. Inguinal herniation
 1. Causes and signalment (Figure 47-9)
 a. Usually seen only in stallions
 b. Can be congenital but should resolve by 3 to 6 months of age
 c. Acquired hernias may be associated with exercise or breeding
 d. Standardbreds, Tennessee walking horses, and saddlebreds are thought to be predisposed
 2. Clinical signs
 a. Scrotal swelling (reducible in foals, but not in acquired form)

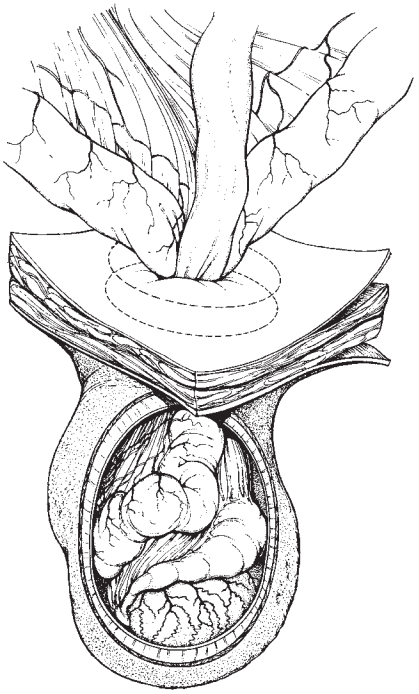


Figure 47-9 Inguinal hernia. Intestine protrudes through the vaginal ring into the inguinal canal or scrotum. The intestine lies within the vaginal cavity. (From Auer JA, Stick JA. *Equine Surgery*, 3rd ed. St Louis, 2006, Saunders.)

 b. Colic secondary to a strangulating or obstructive lesion affecting the small intestine (pain, small intestinal distension, NG reflux)
 c. Pain related to ischemia of testicle on affected side (herniated bowel restricts blood flow through testicular artery and vein)
 3. Diagnosis
 a. Identification of an enlarged scrotum
 b. Rectal palpation can identify loops of intestine running into the internal inguinal canal. In smaller and younger horses, this may not be possible, and transabdominal ultrasound can be used to visualize the ventral abdomen
 4. Treatment: Exploratory celiotomy to reduce entrapped intestine; castration of herniated side with closure of inguinal ring
 5. Prognosis and complications
 a. Usually related to the health of the small intestine and whether resection and anastomosis are necessary
 b. Unilateral castration is almost always necessary on the herniated side. It is assumed that the remaining testicle should not need to be removed, so if the horse is a breeding animal, this should be able to continue
 C. Testicular neoplasia
 1. Causes and signalment
 a. Sertoli cell, Leydig cell tumors, seminomas, teratomas, and carcinomas
 b. Low incidence may be related to limited number of male horses that are not routinely castrated

c. Seminomas are most common, and Leydig cell tumors may be endocrinologically active
2. Clinical signs: Testicular enlargement or change in shape; signs of excess levels of estrogens or androgens if a Leydig cell tumor is present
3. Diagnosis: Clinical signs, testicular biopsy or aspirate; ultrasound may identify altered structure of testicle
4. Treatment: Unilateral castration is recommended, as most of these tumors are not considered to be aggressively metastatic
5. Prognosis and complications: Castration is usually curative; metastasis can occur (thickening of the spermatic cord or enlargement of sublumbar lymph nodes may be suggestive)

II. Penis and prepuce
A. Penile or preputial injuries
1. Cause and signalment
a. Traumatic and can be either lacerations or blunt trauma
b. Hematomas can result following injury
2. Clinical signs
a. Severe swelling associated with sheath and penis to the extent that penis may not be able to be extruded from sheath (phimosis) or that penis may not be able to be retracted into the sheath (paraphimosis)
b. Hemorrhage from any laceration
c. Hematuria may reflect urethral damage
3. Diagnosis: Identification of injury, physical exam, and history
4. Treatment
a. Open wounds can be debrided and sutured if fresh
b. Superficial wounds can be managed as open wounds
c. Swelling and edema may not resolve without application of a support strap (jock strap) to maintain penis within sheath or against the abdomen
d. Antiinflammatories and hydrotherapy
e. Pressure wraps to reduce edema (usually under general anesthesia)
f. Phallectomy if severe urethral trauma (geldings)
g. Sexual rest
5. Prognosis and complications
a. Urethral stenosis if it is lacerated and heals by second intention
b. Hemorrhage can recur if the horse is sexually stimulated
c. Laceration into the deeper venous structures can lead to enlargement of the hematoma, which may require surgical repair of the tunica albuginea if the horse is to be used for breeding in the future

B. Paraphimosis
1. Cause and signalment
a. Inability to retract the penis within the sheath; usually caused by edema secondary to trauma, systemic disease with cachexia, or neurologic disease (e.g., equine herpesvirus type 1, rabies)
b. Rare following acepromazine administration in intact male horses
2. Clinical signs: Penis remains out of sheath, and cannot be retracted even when stimulated; penile edema with excoriation of epithelium; other signs associated with the underlying cause
3. Diagnosis is based on clinical signs
4. Treatment
a. Any underlying disease or condition needs to be addressed
b. Supporting the penis in a sling/jock strap to limit further edema
c. Manually replace penis and hold by purse-string or towel clamps (not always possible and not good long-term treatment)
d. Compression bandages
e. Application of emollient or antibiotic cream to limit excoriation or formation of cellulitis
f. Cold hosing and antiinflammatories
5. Prognosis and complications depend on underlying cause
a. Trauma induced paraphimosis will usually respond rapidly to conservative therapy
b. Refractory paraphimosis may require phallectomy or phallopexy to prevent further injury
c. Cicatrix formation may be resolved by phallectomy or in some cases by circumcision (reefing)

C. Phimosis
1. Causes and signalment
a. The inability of the horse to extrude its penis from the prepuce
b. Usually is acquired, secondary to either tumors or cicatrix formation at the preputial orifice
c. Accumulation of urine within the prepuce creates inflammation, which can cause further cicatrix formation
2. Clinical signs: Preputial edema; inability to extrude penis, even with sedation
3. Diagnosis: Clinical signs; palpation of sheath and, if possible, penis through preputial orifice
4. Treatment: Surgical release of the cicatrix is necessary, followed by circumcision (reefing) to repair or remove cicatrix
5. Prognosis and complications
a. If the traumatized tissue can be resected, horses should recover well
b. Hemorrhage following surgery can lead to hematoma formation
c. Tumors may require phallectomy, or if metastasis has occurred, prognosis can be poor

D. Priapism
1. Causes and signalment
a. Usually only occurs in stallions
b. Secondary to phenothiazine sedatives (acepromazine) or general anesthesia

2. Clinical signs: An erection that persists without sexual excitement
3. Diagnosis: Based on clinical signs
4. Treatment
 a. Slow IV injection with benzotropine mesylate
 b. Intracavernosal injection with dilute phenylephrine
 c. Irrigation and lavage of the corpus cavernosum
 d. Surgical creation of a shunt between the corpus cavernosum and corpus spongiosum
5. Prognosis and complications: May recur; horse may be unable to achieve an erection. Phallectomy indicated in refractory cases

E. Neoplasia
1. Causes and signalment
 a. Squamous cell carcinomas are most common. Sarcoids, melanomas, squamous cell papillomas, and hemangiomas can also occur
 b. Occur frequently in older horses with nonpigmented genitalia
2. Clinical signs: Mass or ulcerated plaque on the prepuce or penis, malodorous discharge (purulent or blood stained) originating from the prepuce; dysuria if the mass impinges on the urethra or urethral orifice
3. Diagnosis: Histopathology of biopsy; clinical signs (differentiate from habronemiasis)
4. Treatment
 a. Surgical excision of mass or reefing if larger area involved
 b. Cryotherapy
 c. Chemotherapy: Topical 5-FU can be applied at 2-week intervals or cisplatin can be injected intralesionally every 2 weeks
 d. Combination therapy may be necessary
 e. Phallectomy to treat lesions involving the distal portion of the penis
 f. En bloc penile resection may be necessary if lymph node involvement is suspected
5. Prognosis and complications: Prognosis is good if tumor does not involve inguinal lymph nodes or cavernous tissues; tend to be locally invasive rather than metastatic. En bloc resection of the penis is sometimes necessary

F. Habronemiasis
1. Causes and signalment
 a. Also known as "summer sores"; caused by migration and encystment of larvae of the equine stomach worm, *Habronema*. Larvae excreted in feces, ingested by fly maggots; flies shed larvae when they feed
 b. Seen in spring and summer, when it is warmer and the fly population is higher. In cold weather, this disease is rarely seen
 d. This is a hypersensitivity reaction to the presence of the larvae
2. Clinical signs: Lesions seen on preputial orifice and preputial ring; can be ulcerated, granulomatous, and extensive
3. Diagnosis: Based on clinical signs (differentiate from squamous cell carcinoma); impression smears, histology (eosinophils, giant cells, granules, larvae)
4. Treatment
 a. Fly control is important for management
 b. Ivermectin administered PO to kill larvae and adult worms
 c. Prednisolone given to reduce the inflammatory reaction to larvae
 d. Topical application of corticosteroid and organophosphate cream may help kill the larvae and reduce the inflammation
 e. Surgical resection or phallectomy can be performed
5. Prognosis and complications: Some appear more susceptible with annual recurrences; without proper worming and fly control, this disease is likely to recur or affect other horses in a barn

III. Vulva, vagina, and cervix

A. Pneumovagina
1. Causes and signalment
 a. Seen usually in older mares, secondary to aging, poor nutritional condition, or foaling injuries
 b. Poor perineal conformation, where the anus sinks cranially and drags the dorsal commissure of the vulva into a more horizontal orientation, disrupts the normal airtight seal of the vulva
2. Clinical signs: Reduced fertility due to uterine and vaginal inflammation, abnormal perineal conformation, often with the vulva's orientation visibly more horizontal; foamy vaginal discharge may be present
3. Diagnosis: Based on clinical signs
4. Treatment
 a. Caslick's procedure (episioplasty) can be performed to recreate airtight seal of vulva
 b. Perineal body transection requires dissection between the anus and the dorsal commissure of the vulva until a more vertical vulvar orientation is achieved. The muscular attachments between the structures are transected, which frees up the vulva
 c. Perineal body reconstruction can be performed to recreate permanently a more secure, airtight seal in the proximal portion of the vulva
5. Prognosis and complications: Treat urovagina if present. Caslick's and perineal body reconstructions will often need to be either removed or transected to allow foaling to occur without further trauma

B. Urovagina
1. Causes and signalment: Also known as urine pooling; more common in older, thinner, multiparous mares with poor perineal conformation. Presence of urine leads to inflammation of the vagina, cervix, and uterus, reducing fertility

2. Clinical signs: Vaginoscopy reveals accumulation of urine in the fornix, but this may only be seen when the mare is in estrus
3. Diagnosis: Clinical signs and evidence of urine pooling
4. Treatment: Improve nutritional condition, perform urethral extension. Perineal body transection (see pneumovagina) can be used to improve perineal conformation to allow urine to drain externally rather than cranially
5. Prognosis and complications: Fistula formation is common; repair once inflammation has subsided (should resolve rapidly once urine accumulation is prevented)

C. Perineal lacerations
1. Causes and signalment
 a. More commonly occur in primiparous mares during an unassisted foaling
 b. Due to malpositioning of the foal's limbs, the foot is pushed dorsally into the roof of the vestibule resulting in trauma to different structures
 c. Three types of perineal laceration are described:
 (1) First-degree perineal lacerations involve only the vestibular mucosa and the dorsal commissure of the vulva
 (2) Second-degree perineal lacerations involve the vestibular mucosa, submucosa, and muscles of the perineal body
 (3) Third-degree perineal lacerations involve a complete disruption of the tissue between the rectum and the vestibule. These usually also damage the perineal body muscles and the anal sphincter. If the foal's foot position is corrected before disruption of the perineal body and anal sphincter, a rectovaginal fistula develops instead of a complete laceration
2. Clinical signs: Varying degrees of trauma to vestibule, vulva, rectum and anus; fecal contamination of vestibule if third-degree perineal laceration or fistula present
3. Diagnosis. Based on clinical signs
4. Treatment
 a. First-degree perineal lacerations usually only require wound management but may need a Caslick's to prevent pneumovagina
 b. Second-degree perineal lacerations should be treated with a Caslick's and a perineal body reconstruction, once the inflammation has subsided (at least 4 weeks post foaling)
 c. Third-degree lacerations and fistulas require surgical repair. This should be performed at least a month post foaling, but a longer delay is helpful to allow scar tissue formation (makes closure easier as tension on suture line is decreased)
 d. Fecal softeners are indicated to reduce the risk of obstipation
5. Prognosis and complications
 a. Fertility has been shown to be good following surgical repair
 b. Once a mare has had a laceration, the risk of a laceration at future foalings does not appear to be increased
 c. Surgical repairs have a high rate of dehiscence. Keeping fecal matter soft for at least 3 to 4 weeks postoperatively is recommended to prevent obstipation and straining

D. Cervical lacerations
1. Causes and signalment: Foaling injury; occur more frequently during assisted delivery for dystocia or during fetotomy
2. Clinical signs: Chronic infertility (poor conception rates and early fetal abortion), endometritis
3. Diagnosis: Cervical palpation during diestrus
4. Treatment: Surgical repair of the laceration is recommended
5. Prognosis and complications: Reduced fertility continues if laceration not repaired; adhesions or cervical incompetence develops if untreated. If treated, prognosis is good for breeding soundness

IV. Ovaries

A. Ovarian tumors
1. Causes and signalment: Granulosa cell tumors are most common; seen in all ages (more frequent in older mares). Usually unilateral, slow to metastasize, can be significantly enlarged
2. Clinical signs: Abdominal pain associated with flank or riding; altered behavior (continued or intermittent estrus, nymphomania, stallion-like behavior, abnormal aggression)
3. Diagnosis
 a. Rectal palpation: One enlarged ovary (can be extremely enlarged); contralateral ovary abnormally small and not reproductively active
 b. Repeat rectal exam: Enlargement of the affected ovary, rather than regression in size
 c. Transrectal ultrasound can reveal a multilobulated, cystic interior
 d. Elevated inhibin levels in the blood
4. Treatment: Unilateral ovariectomy; bilateral if horse not used for breeding. Surgery performed standing via colpotomy, laparoscopy, flank laparotomy; under general anesthesia via laparoscopy or ventral laparotomy
5. Prognosis and complications
 a. Postoperatively mares will often be unusually uncomfortable (usually more so following a colpotomy or laparotomy), requiring careful monitoring and judicious use of analgesics
 b. Following a colpotomy, there is a risk of intestinal evisceration through the vaginal incisions
 c. Hemorrhage from the ovarian pedicle is a major concern and postoperative hemorrhage is a risk

 d. Laparoscopic ovariectomy is the treatment of choice, but some tumors may be too large to permit this approach
 e. The contralateral ovary may take up to a year before it can resume normal reproductive activity
B. Non-neoplastic conditions
 1. Causes and signalment: Hematomas, cysts, or abscesses (rare); any age of horse
 2. Clinical signs: Abdominal pain during riding or flank palpation; altered behavior (related to discomfort)
 3. Diagnosis: Rectal palpation reveals enlarged ovary; contralateral ovary is often normal. Ultrasound of affected ovary reveals abnormal architecture
 4. Treatment: Ovariectomy is indicated
 5. Prognosis and complications: Hemorrhage from ovarian pedicle, abdominal discomfort; should be fertile if condition is unilateral

V. Uterus
A. Uterine cysts
 1. Causes and signalment: Occur in older mares
 2. Clinical signs: Infertility
 3. Diagnosis: Transrectal ultrasound, hysteroscopy
 4. Treatment: Cyst ablation using diode laser via hysteroscopy or using mechanical or chemical methods
 5. Prognosis and complications: Cyst ablation should improve fertility; recurrence if cyst not completely destroyed
B. Uterine torsion
 1. Causes and signalment: Pregnant mares, usually last 2 months of gestation; torsion clockwise or counterclockwise
 2. Clinical signs are of colic
 3. Diagnosis: Rectal examination; one broad ligament that is tight, coursing dorsally from the caudal edge of the uterus; exclusion of GI source for colic
 4. Treatment: Rolling horse while anesthetized to correct torsion; surgery either standing via flank laparotomy or under general anesthesia via celiotomy
 5. Prognosis and complications: Most will survive and produce a live foal; if severe, uterus can be devitalized, ruptured, or torn necessitating cesarean section, hysterectomy, or repair of damaged uterus
C. Uterine artery hemorrhage
 1. Causes and signalment: Occurs within first several days postpartum; more common in older mares
 2. Clinical signs: Moderate to severe colic; hemorrhagic shock (pale mucous membranes, tachycardia, weak peripheral pulse)
 3. Diagnosis: Clinical signs, history of recent foaling; rectal examination reveals edematous broad ligament with possible palpable mass (hematoma)
 4. Treatment: Supportive therapy; no good surgical therapy
 5. Prognosis and complications: Many either found dead or will die; significant risk of recurrence at subsequent foaling

Supplemental Reading

Aver JA, Stick JA. *Equine Surgery,* 3rd ed., St Louis, 2006, Saunders.

Reed S, Bayly W, McEachern RB, and Sellon D. *Equine Internal Medicine,* 2nd ed., St Louis, 2003, Saunders.

Robinson NE, Sprayberry KA. *Current Therapy in Equine Medicine,* 6th ed., St Louis, 2006, Saunders.

Ross MW, Dyson SJ. *Diagnosis and Management of Lameness in the Horse,* 1st ed., St Louis, 2003, Saunders.

48 CHAPTER

Urinary Disorders

Rebecca S. McConnico

ACUTE RENAL FAILURE

I. Abrupt cessation of renal function
 A. Results in accumulation of nitrogenous wastes
 B. Fluid imbalances
 C. Electrolyte imbalances
II. Serum biochemistry abnormalities
 A. Elevation in blood urea nitrogen (BUN)
 B. Serum creatinine elevation (Cr)
 C. Collectively known as *azotemia*
 1. Prerenal azotemia: Decreased kidney perfusion; in strict prerenal azotemia, horses will pass urine > 1.020
 2. Renal azotemia: Primary malfunction of the kidneys
 3. Postrenal azotemia: Blockage of urine excretion
III. Causes of equine azotemia
 A. Most common cause of azotemia in horses is hemodynamic causes such as dehydration
 B. Additional causes are acute tubular necrosis (ATN) due to renal toxins
 C. Progression of prerenal-induced ischemic tubular damage
 D. Reversible if treated appropriately
IV. Causes of prerenal azotemia
 A. Acute enteritis: Diarrhea is the clinical sign
 B. Colic: Abdominal pain is the clinical sign
 C. Prolonged exercise: Exhaustion is the clinical sign
 D. Acute blood loss: Pale mucous membranes are a clinical sign
 E. Cardiac insufficiency: Weakness and pale membranes are clinical signs
V. Treatment
 A. Replacement of plasma volume will correct prerenal azotemia
 B. ATN plus prerenal azotemia: Will often result in pulmonary edema or peripheral edema once fluids have been replaced
VI. Cause
 A. Tubular obstruction by sloughed cellular debris (Tamm Horsefall mucoproteins or heme proteins)
 B. Back leak of the glomerular filtration through the damaged tubular cells
 C. Primary reduction in glomerular filtration rate (GFR) through reflex shunting arteriolar circulation away from obstructed nephrons or glomerular capillary permeability decreasing through swelling or mesangial contraction

ACUTE TUBULAR NEPHROSIS

I. Causes
 A. Hemodynamic imbalance
 B. Toxins
 C. Medications
 1. Aminoglycosides
 2. Certain sulfonamides
 3. Polymyxin B
 4. Phenylbutazone (and other nonsteroidal antiinflammatory drugs)
 5. Menadione sodium bisulfite (vitamin K_3)
 D. Endogenous pigments
 1. Hemoglobin
 2. Myoglobin
 E. Plant toxins
 1. Oak
 2. Wilted red maple leaves
 3. Wild onion
 4. White snakeroot
 F. Heavy metals: Mercury
 G. Cantharadin: Blister beetles
II. Postrenal causes
 A. Ruptured bladder in newborn foal
 B. Uroliths: Adult
III. Pathogenesis: Accumulation of nitrogenous wastes in the blood (elevations in serum creatinine and BUN)
IV. Diagnosis
 A. Elevated Cr and BUN
 B. Urinalysis
 1. Urine specific gravity less than 1.020 in the presence of clinical dehydration suggests intrarenal disease
 2. Color of urine: The presence of heme pigments
 3. Sediment analysis
 a. Normal reveals considerable mucus and calcium carbonate crystals
 b. Casts are easily overlooked because they dissolve easily
 C. Renal ultrasound: Cyst or structural changes
 D. Nuclear medicine techniques: GFR
 E. Renal biopsy: Perform only when there is the necessity to know prognosis because of complications of severe hemorrhage
V. Treatment
 A. Correction of fluid, electrolyte, and acid-base disorders

B. Use physical examination, packed cell volume, total serum, or plasma proteins to determine hydration and cardiovascular status
C. Oral fluids
1. Well tolerated
2. Water
3. Isotonic fluid
4. Balanced electrolyte fluid
D. Intravenous therapy: Indicated for animals with gastrointestinal disease
E. Furosemide, dopamine, or both: Indicated in horses that are anuric
F. Additional considerations: Treat sepsis and other underlying diseases, and discontinue potentially nephrotoxic drugs

VI. Foals
A. May have elevated Cr levels normally; does not necessarily mean patient has renal compromise
B. Newborn foals have hyposthenuric urine (<1.010)

CHRONIC RENAL FAILURE

I. Progressive loss of nephrons (number or function)
II. Glomerulonephritis: Usually immune-mediated related and the most common form in horses
III. Can occur in horses of any age, breed, sex
IV. Chronic weight loss, anorexia, polyuria are key signs
V. Clinical findings
A. Chronic weight loss
B. Anorexia
C. Polyuria
D. Dependent edema if there is significant protein loss
VI. Causes: Circulating immune causes (e.g., viral [equine infectious anemia, bacterial [*Streptococcus* spp.], or parasitic antigens → activation of complement system)
VII. Pathogenesis
A. Decreased GFR levels
B. Loss of plasma electrolytes (especially sodium, chloride, phosphate)
C. Resulting clinical signs are diuresis, polyuria, and polydipsia
D. Decreased sodium retention leads to bicarbonate loss with decreased hydrogen ion excretion → acidosis
VIII. Diagnosis and laboratory findings
A. Moderate azotemia and isosthenuria
B. Persistent proteinuria
C. Hypoproteinuria
D. Hypoalbuminemia
E. Hypercalcemia
F. Renal biopsy, although risk of hemorrhage
IX. Treatment
A. Usually no treatment because usually recognized only when permanent renal insufficiency has occurred
B. Corticosteroids may be used to reduce the effects of immune complex disease
C. Diet: High-quality carbohydrate diet (low protein diet)
D. Plasma transfusion: Temporary relief of edema

TUBULOINTERSTITIAL DISEASE

I. No breed, sex, or age predilection
II. Clinical signs
A. Similar to chronic renal failure for glomerulonephritis without hypoproteinemia, polyuria, and polydipsia
B. Left kidney may palpate smaller than normal
III. Causes: May be secondary to acute tubular nephrosis
IV. Diagnosis
A. Clinical signs
B. Azotemia
C. Isosthenuria
D. Electrolyte abnormalities: Urine clearance values
E. Renal ultrasound: May identify renal mass or renal pelvis
V. Cause: Tubulointerstitial disease may be secondary to ATN
A. Aminoglycosides
B. Mercury toxicity
C. Pyelonephritis
D. Hydronephrosis, myoglobinuria
E. Acute myositis
F. Nephrolithiasis
VI. Treatment
A. Management includes dietary management: Low-protein diet, low calcium diet (no alfalfa); provide salt block; good quality feed
B. Correct any prerenal component
C. Anabolic steroids maybe helpful
D. B vitamins
E. Sodium bicarbonate: If the level goes below 18 (dose is 225 g/day via oral route)

PYELONEPHRITIS

I. Usually occurs in females (can occur in males with bladder paralysis)
II. Clinical findings
A. Often subclinical
B. Frequent urination
C. Pus in the urine
III. Causes
A. Bacteria isolated: *Escherichia coli* and other gram-negative organisms
B. Can follow parturition, can be associated with paralyzed bladder, or can occur without any identifiable risk factor
C. Urine stasis
D. Shortened urethra
IV. Diagnosis and laboratory tests
A. Urinalysis
1. Pyuria
2. Proteinuria
3. Hematuria
B. May have signs of systemic disease: Neutrophilic leukocytosis, elevated fibrinogen, hypergammaglobulinemia
C. Azotemia may be restricted to the renal pelvis
D. Renal ultrasound: Enlarged renal pelvis, pelvis containing purulent material
E. Urine culture: Causative organism

V. Treatment
 A. Treatment for any predisposing factor
 B. Antimicrobial therapy based on culture and sensitivity
 C. Catheterize atonic bladders

LOWER URINARY TRACT DISORDERS

I. Cystitis
 A. Uncommon but may occur in adult females postpartum
 B. Clinical signs
 1. Pollakiuria
 2. Perineal scalding (focal alopecia)
 3. Bladder may be thickened on rectal palpation
 C. Causes
 1. Primary disease is rare
 2. Secondary disease is secondary to urine retention, such as with urolithiasis, bladder atony, paralysis, late pregnancy, dystocia, sorghum or sudan grass toxicity with ascending myelomalacia in horses
 D. Diagnostic plan
 1. Sterile urinalysis and culture
 2. Complete blood cell count is usually normal
 E. Treatment: Antibiotics (reach good levels in the urine)
 1. Penicillin
 2. Ampicillin
 3. Cephalosporins
 4. Trimethoprim sulfa
II. Urinary incontinence
 A. Usually associated with neurologic disease (sacral fractures, infectious or inflammatory myelitis)
 B. Bladder tumors are rare
 C. Anatomic defects
III. Patent urachus: Spontaneously closes at birth; however, may be associated with septic omphalophlebitis; requires an omphalectomy (Figure 48-1)
IV. Ectopic ureters are rare
V. Bladder rupture in horses
 A. Most common in male foals (can also occur in female foals); can occur in mares after foaling
 B. Can be life threatening
 C. Increases risk of septicemia
 D. Requires surgery for repair
 E. Clinical signs
 1. Abdominal enlargement with intra-abdominal fluid accumulation
 2. Frequent attempts to urinate (Figure 48-2)
 F. Causes: In male horses, narrow pelvis, long urethra; allows for increased pressure buildup
 G. Diagnosis
 1. Abdominocentesis
 2. Cr level, methylene-blue contrast, calcium carbonate crystals
 H. Clinical pathology
 1. Hyponatremia
 2. Hypochloremia
 3. Hyperkalemia
 I. Treatment
 1. Surgery
 2. Fluid drainage
 3. Fluid therapy
VI. Obstructive urolithiasis in horses
 A. Some males may have a calculus that lodges in the urethra
 B. Clinical findings
 1. Hematuria
 2. Urine scalding
 3. Stranguria
 4. Urine dribbling
 5. Pollakiuria
 C. Diagnostics and laboratory tests
 1. Cystoscopy and ultrasound
 2. Urinalysis reveals crystals and free red blood cells
 D. Therapeutic plan
 1. Stones can be removed
 2. Urinary acidifiers may be useful



Figure 48-1 Marked enlargement of the umbilicus is evident in this male foal with septic omphalophlebitis and patent urachus. (From Auer JA, Stick JS. *Equine Surgery*, 3rd ed. St Louis, 2005, Saunders.)



Figure 48-2 A 2-day-old foal exhibiting stranguria caused by a ruptured bladder. Note the caudal position of the hindlegs, suggesting that the foal is straining to urinate rather than defecate. Differentiating between stranguria and tenesmus (meconium impaction) is not always easy. (Smith, Bradford P.. *Large Animal Internal Medicine,* 4th ed. St Louis, 2009, Mosby.).

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SECTION IV FOOD ANIMAL

Bovine Medicine and Management

49 CHAPTER

William Raphael and Daniel L. Grooms

HUSBANDRY

I. Nutrition
 A. All ruminants have special capacity to ferment fiber in the forestomachs to produce propionic, acetic, and butyric acids
 B. Fiber measured as acid detergent fraction or neutral detergent fraction (ADF + hemicellulose)
 1. Dairy: Ensiled feeds, corn silage and alfalfa haylage, predominate
 2. Beef: As above for feedlots, pasture for cow-calf operations
 C. Propionic acid is gluconeogenic in the liver
 D. Acetic and butyric acids are lipogenic in adipose and the udder
 E. Bacterial fermentation of soluble sugars and starch can occur rapidly and lead to overgrowth in *Lactobacilli* spp. and *Streptococcus bovis*, with rumen pH decreasing to less than 5.0
 F. Butyric and propionic acids important for rumen pilli growth
 G. Fermentation chamber is also a source and starch of protein
 1. Bacterial death and passage out of forestomachs represent an excellent quality and an efficient source of protein for the ruminant
 2. Energy and protein are fed to maximize rumen microbial protein synthesis of this manner, then extra protein requirements (e.g., lactating dairy cow) are met by feeding rumen-protected protein, which is absorbed in the intestinal tract and not consumed by rumen microbes
 H. Calcium
 1. Metabolism can be manipulated by feeding chloride or sulfate salts to diet so that it is close to neutral in electrical charge
 2. Effect is easily monitored by measuring urine pH
 3. Desired urine pH = 5.5 to 6.5
 4. Normal bovine urine pH = 8.0
 5. Numerous mechanisms, one of which involves parathyroid hormone (PTH) receptor shape change, resulting in more efficient bone calcium mobilization at commencement of lactogenesis, and hence prevention of hypocalcemia (milk fever)
 6. Typically implemented for 2 to 3 weeks prepartum in dairy cattle
 I. Energy balance
 1. Body condition scoring
 2. Five-point scale (dairy)-Subjective measure
 J. Metabolic profile testing
 1. Random selection of an appropriate number of cows to get representative metabolic profile of the entire group in that particular stage of the production cycle
 2. Nonesterified fatty acids, β-hydroxybutyric acid
 a. Quantify energy balance
 b. Commonly measured in cows close to calving
 c. Correlate with dietary composition, preparation, delivery, and consumption, and all variables affecting these
 3. Urea, albumin
 a. Quantify protein metabolism
 b. Commonly measured in cows prebreeding, urea often in milk
 c. At high concentrations, urea is thought to negatively affect fertility
 4. Micronutrients (e.g., vitamin E, selenium) to diagnose deficiency or toxicity
 K. Mycotoxins
 1. Nomenclature
 a. Aflatoxins
 (1) *Aspergillus* molds
 (2) Warmer climates (e.g., South)
 (3) Toxic at one thousandth the dose of mycotoxins
 b. Mycotoxins (e.g., vomitoxin [deoxynivalenol, DON], T2, fumonisins, zearalenone
 (1) *Fusarium* molds
 (2) Colder climates (e.g., Midwest)
 (3) Toxic at parts per million (ppm)
 2. *Fusarium* mold growth occurs in standing crop, extremely rare in forages
 3. Enzyme-linked immunosorbent assay (ELISA) tests are not reliable in forages
 4. Little is known about the effects of exposure on health and productivity. 0.5 to 2.0 ppm vomitoxin may be a problem

5. Efficacy of dietary binding agents is questionable
6. Contaminated feedstuffs should be fed at diluted rates or discarded

L. Gossypol toxicity
1. Possible when excessive quantities of whole cottonseed or meal are consumed
2. Clinical signs vary. Gastrointestinal (GI) mucosal hemorrhage and necrosis, cardiac and skeletal muscle and hepatic necrosis can occur. Male infertility (compromised spermatogenesis, proximal droplets, recoverable) is the most common effect
3. Feed less than 6 to 8 lb/day to lactating cows, avoid in bulls

M. Sodium toxicity
1. Most common in calves, when water has been withheld, and most common in winter in cold climates when water sources have frozen and milk replacer may be fed at high concentrations
2. Pathophysiology: Hypernatremia, acute intravascular hemolysis, cerebral edema
3. Clinical signs present shortly after water ingestion
 a. Blindness, hyperexcitation, recumbency, coma
 b. Hemoglobinuria, hemoglobinemia, anemia
4. Treatment: Grave prognosis. Involves slow dilution of serum sodium with decreasing (toward normal) concentrations of sodium containing intravenous (IV) solutions

II. Housing

A. Ventilation
1. Determinant of respiratory health
2. Removes exhaled microbes and water and volatized chemical irritants (NH_3) from animals' environment
3. Concentration of upper respiratory tract flora in inspired air increases in poorly ventilated environments, resulting in deeper colonization of the respiratory tract
4. Can be achieved without motorized equipment. e.g., open eaves, ridges, side and end walls

B. Flooring
1. Always concrete
2. Determinant of hoof health
3. Excessive hoof wear from concrete can exist. Also determined by distances cows are walking and presence of other abrasive material (e.g., bedding material)
4. Interdigital dermatitides transmitted from unsanitary walking surfaces

C. Bedding
1. Sand is superior in comfort and sanitation
2. Represents challenges in manure removal because it is nonmiscible
3. Many mattress styles are alternatives to sand
 a. Less day-to-day maintenance is required than sand stalls
 b. Can be uncomfortable for cows, leading to hygromas and pressure lesions over bony prominences

D. Stray voltage
1. Rare but possible cause for ill thrift. Occasionally legitimately diagnosed as cause of behavioral changes (e.g., feeding, milking, moving behaviors). Common misdiagnosis of many metabolic and infectious diseases
2. Caused by low voltage electric shock, which may not be detectable to producer
3. Sources include distribution network and farmstead wiring
4. Prevented by maintaining electrical systems to best possible standards

E. Electrocution
1. Sources are usually lightning strike, fallen transmission line, or barn short
2. Pathophysiology: Nervous shock, nervous tissue necrosis, burns (from contact point to ground), fractures (possibly because of sudden, profound muscle contraction)
3. Clinical signs: Sudden death with skin burns, or bone fractures, temporary unconsciousness with residual depression, blindness, ataxia, skin sloughing

MANAGEMENT

I. Dairy

A. Products are milk, beef, and replacement heifers

B. Milk production measured as daily cow average (lb) or cow lactation average (standardized to first 305 days of lactation and adjusted for age, season, and region [305 ME])

C. Goal is to calve annually

D. Calves are weaned from dam at birth and from milk (or milk replacer) at approximately 8 weeks of age

E. Goal is for first calving at 23 to 24 months of age, conceiving at 14 to 15 months and 850 lb body weight, 51 inches tall at withers

F. Predominant breed is the Holstein. Other common breeds in the United States include Jersey, Ayrshire, Guernsey, Brown Swiss, and Milking Shorthorn.

G. Recombinant bovine somatotropoin (rBST) administered in some regions of the United States, although a large drop in consumer demand for milk produced this way occurred in 2007/2008.
1. Administered from 57 days after calving
2. Approximately 10-lb increase in daily milk production
3. Safe to animals and consumers

H. First breeding not usually before 60 days after calving (days in milk)

I. Hormonal reproductive synchronization commonly used
1. Ovsynch, gonadotropin-releasing hormone (GnRH) day 0, prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) day 7, GnRH day 9, artificial insemination (AI) day 10
2. G6G/Ovsynch preceded by GnRH by 6 days, and $PGF_{2\alpha}$ by 8 days
3. Presynch, Ovsynch preceded by $PGF_{2\alpha}$ by 12 and 26 days

J. Genetic selection
1. Milk production
2. Conformation
3. Also fertility, milk somatic cell score, calving ease

K. Longevity: Two to three lactations

L. Vaccination
1. Leptospirosis, especially *Leptospira borgpetersenii serovar hardjo* (type: hardjo-bovis), at young age
2. Respiratory viruses (bovine viral diarrhea [BVD] types 1 and 2, bovine respiratory syncytial virus [BRSV], infectious bovine rhinotracheitis [IBR], parainfluenza-3 [PI-3], around time of weaning and then annually
3. Clostridial diseases
4. *Escherichia coli* bacterins, aid in prevention of coliform mastitis
5. Miscellaneous others

M. Parasite control
1. Internal parasites cause disease in young cattle. Housed cattle are at decreased risk than grazing cattle, but parasitism still occurs
 a. *Eimeria* spp., weaning to 8 months
 b. Helminths (*Ostertagia ostertagi, Trichostrongylus* spp., *Cooperia* spp., *Nematodirus* spp.), weaning to first calving
 c. Control by selective deworming, rotational grazing (if appropriate), and monitoring of fecal egg counts for detection of anthelmintic resistance
 d. All internal parasitism can be controlled by reducing egg burdens in the animals' environment, with sound management practices such as regular bedding and barn cleaning
2. Lice cause pruritis and alopecia in winter months and can contribute to transmission of ringworm. Treat with late fall, early winter endectocide

II. Beef

A. Industry segments
1. Seed stock: The segment of the industry that specializes in breeding cattle with high genetic merit for sale to the commercial cow-calf industry
2. Commercial cow-calf: The segment of the industry that focuses primarily on reproducing cattle for food supply
3. Stocker-backgrounder: The segment of the industry that takes weaned calves destined for food supply and adds lean weight to them using low cost feeds such as pasture
4. Feedlot: The segment of the industry that fattens cattle destined for food supply using primarily high concentrate diets

B. Beef life cycle
1. Breeding: Cows are bred during a limited period, often 60 to 90 days
2. Calving: Typically timed to coincide with a period when high-quality feeds are readily available to support milk production for newborn calves
3. Weaning: Typically 4 to 6 months of age. Weaned calves are destined to become either breeding herd replacements (heifers or bulls) or to be fed out for slaughter
4. Stocker-backgrounder-feedlot: These animals are not used for breeding and enter the fed cattle segment of the beef industry, a terminal enterprise

C. Performance parameters
1. Expected progeny differences: An estimate of the genetic value of an animal as a parent
2. Birth weight
3. Weaning weight: Adjusted to 205 days of age
4. Yearling weight
5. Pregnancy rate: Number of cows pregnant over the number of cows bred
6. Calving percentage: Number of calves born over the number of cows bred
7. Weaning percentage: Number of calves weaned over the number of cows bred
8. Average daily gain
9. Feed conversion efficiency: Pounds of feed per pound of gain
10. Body condition score: Subjective evaluation of the body condition of cows. Used to manage nutritional programs. Beef scale is 1 to 9; 1 is thin or underconditioned, and 9 is fat or overconditioned
11. Percent Choice: Percent of feedlot cattle that were graded as Choice or higher at slaughter using the USDA Carcass Quality Grade Standards.

D. Cow calf industry
1. Breeding management
 a. Breeding season: Typically lasts 60 to 90 days. By condensing breeding season, resources are used more efficiently
 b. Breeding methods
 (1) Bulls, natural service
 (a) One bull per 20 to 40 cows
 (b) Breeding soundness examination (BSE) before breeding season, consisting of the following:
 i. Physical examination for defects that might prevent bull from breeding cows (lameness, blindness)
 ii. Examine reproductive tract, including testicles, scrotum, prostate, seminal vesicles, inguinal rings, prepuce, and penis; measure scrotal circumference. Scrotal circumference correlates to volume of semen production, age of maturity of offspring, and pelvic size of daughters
 iii. Collection of semen sample and evaluation for motility, morphology, and evidence of infection (the presence of white blood cells)
 (2) AI: either following estrous or timed following estrous synchronization
 (3) Embryo transfer
 c. Estrous synchronization: Use of a variety of hormonal treatments (e.g., $PGF_{2\alpha}$, GnRH) to

synchronize estrous cycles. Allows efficient use of breeding resources
2. Calving: Calves born in barns, in calving pens and dry lots, or on pasture
3. Passive immunity is derived from colostrum which is ingested by nursing cows
4. Cows raise calves until weaning
 a. Cows fed (most commonly) pasture
 b. Calf growth is dependent on nutrients derived primarily from milk
 c. Calves may be offered supplementary grain (creep feed)
5. Weaning: Calves weaned 4 to 6 months after birth; raised separate from cows

E. Seed stock industry
1. Management is similar to cow-calf industry
2. More attention is focused on specific matings to produce genetically superior replacement animals

F. Stocker-backgrounder
1. Stocker or backgrounding operations take recently weaned calves and prepare them for the feedlot
2. Goal is to put on weight gain, primarily in the form of structure (muscle and bone) using low cost feeds such as grass or grass-based silage
3. Post-weaning health issues such as bovine respiratory disease (BRD) is managed
4. Cattle are sorted and packaged into larger and uniform groups that are desirable to the feedlot
5. Health protocols
 a. Vaccination against common cattle pathogens including:
 (1) IBR
 (2) Bovine viral diarrhea virus (BVDV)
 (3) BRSV
 (4) PI-3
 (5) *Mannheimia haemolytica* and *Pasteurella multocida*
 (6) *Histophilus somnus*
 (7) Clostridial spp.
 b. Internal and external parasites
 c. Castration and dehorning

G. Feedlot
1. A feedlot or feedyard is the segment of the beef industry used for finishing cattle before slaughter
2. Cattle are typically fed high-concentrate diets to encourage the deposition of intramuscular fat
3. Vaccination and parasite control are similar to background cattle

H. Beef quality assurance or beef quality and safety assurance
1. Voluntary industry driven initiative to reduce the risk of quality and safety defects in the product (meat) provided to consumers
2. Aim is to educate all segments of the industry on management strategies to reduce risk of introducing quality or safety defects
3. Components
 a. Feedstuffs
 (1) Reduce risk of contamination from molds, mycotoxins, or chemicals
 (2) Feeding of ruminant derived proteins is strictly prohibited because of the risk of bovine spongiform encephalopathy (BSE) transmission
 (3) Only Food and Drug Administration-approved medicated feed additives are used
 (4) Extra-label use of feed additives is illegal and strictly prohibited
 b. Records: Accurate, complete, and up-to-date records need to be maintained for all procedures performed or products administered to cattle
 c. Cattle care and husbandry
 (1) Proper cattle handling reduces stress, disease prevalence, carcass bruising, and other quality and safety problems
 (2) Facilities should be designed and maintained for easy and safe handling
 (3) Clean feeding and watering systems
 d. Proper product administration and use
 (1) Use of products according to their label directions
 (2) Observance of label withdrawal recommendations
 (3) Proper administration of products including dosage, route, and location
 (4) All injections should be given in the neck
 (5) When given the choice, injections should be given subcutaneously (SC)

III. Euthanasia of farm animals
A. Often considered for economic reasons alone
B. American Veterinary Medical Association does not approve all methods (determined by humanity and effectiveness and may be conditional on age or species or specifications of device, such as the gauge of gun). e.g.:
 1. Not approved: Exsanguination (by itself), IV solvents or cleaning agents
 2. Approved: Gunshot or captive bolt to head

PRODUCTION MEDICINE SKILLS

I. Understand industry software [DairyComp305, Spartan Dairy II, CPM Dairy]
II. Familiarity with common statistical procedures (chi-square, *t* test) and tools (e.g., statistical process control)
III. Understand financial statements and tools (decision tree analysis) and partial budgets
IV. Understand important risk factors for problems in each management sector
A. Risk factors
 1. Labor: Shift, individual, day of the week, job description, training, and evaluation
 2. Facilities and equipment: Cleanliness, maintenance, age, ventilation, temperature, lighting, dimensions, and purpose
 3. Grouping: Age, production, reproductive status, health status, antibiotic residues, drug withhold times

4. Nutrition: Forage hybrid selection, harvesting and storage techniques, commodity pricing, ration formulation, ration mixing, and feed delivery
5. Season and climate: Negative effects of heat stress on production and fertility, negative effect of cold stress on calf growth
6. Pathogen epidemiology: Virulence factors, environmental persistence, and identification of environmental reservoirs

B. Management sector
1. Maternity facility: Cleanliness, colostrum feeding practices, and dystocia management
2. Calf-raising facility: Cleanliness, assessment of passive transfer of immunity, diagnosis and treatment of disease, milk replacer selection and mixing, starter feed consumption, and the weaning process
3. Heifer facility
 a. Transition heifers: Diagnosis and treatment of disease, forage consumption, growth, and free stall use
 b. Breeding heifers: Heat detection, vaccination status, height and weight
 c. Pregnant heifers: Growth, vaccination status, and abortion rates
4. Close-up heifers: Barn cleanliness, incidence of dystocia, labor intervention practices, and height and weight
5. Close-up cows: Barn cleanliness, incidence of dystocia and milk fever, and labor intervention practices
6. Fresh cows: Barn cleanliness; disease diagnosis, treatment, and incidence; and grouping
7. Breeding herd: Heat detection, synchronization practices, and disease incidence
8. Pregnant herd: Body condition and foot-trimming practices
9. Dry cows: Mastitis and abortion incidence, duration of dry period
10. Parlor: Udder preparation, gross milk inspection, milk bacterial (bulk tank) and somatic cell (bulk tank and individual cow) counts, milking speed, vacuum pressure, liner, and other rubber condition, cleaning materials, and procedures
11. Waste removal and processing: Barn scraping, storage capacity, soil P concentrations, and protection of waterways
12. Forage selection: Silage or seed variety, digestibility, drought tolerance, yield
13. Forage harvest and storage: Dry matter content, bunker filling speed, and packing density
14. Feed commodity purchase and storage: Price hedging, measurement and control of shrink
15. Ration formulation, mixing, feeding: Mixing order, time, and effect; feeding time and order; feed placement; and unconscious feed withhold

SURGICAL TECHNIQUES

I. Abomasopexy for left displacement
A. Right flank pyloro-omentopexy, pyloropexy, or omentopexy
1. Technique
 a. Mid right flank incision, blunt grid dissection of inner layers is optional
 b. Abomasal deflation recommended but optional
 c. Retract abomasum using greater curvature or greater omentum. Pexy abomasum at pyloric antrum either into ventral transverse abdominal muscle and peritoneal incisional closure (#3 chromic catgut, tapered needle, simple interrupted pattern, repeated several times) or just caudal to incision. Pexy omentum in next part of closure (#3 chromic catgut, tapered needle, horizontal mattress pattern repeated several times)
2. Complications
 a. Infection: Mixed flora, gram-negative anaerobes persist; treat with procaine penicillin G, oxytetracycline
 b. Failure to pexy because of peritoneal adhesions
 c. Recurrence is rare

B. Left flank abomasopexy
1. Long nonabsorbable suture passed through greater curvature of abomasum, abomasum deflated, then suture ends passed through right paramedian abdomen on straight cutting needles. Assistant required to retrieve needles and suture as they are passed through the body wall, and to tie the sutures externally
2. Not possible to pexy normally positioned abomasa

C. Paramedian abomasopexy
1. Complications: As above plus abomasal fistula at incision site, usually associated with pexying the abomasum into the incisional closure; rarely occurs when sutures are placed parallel to and away from the incision

D. Blind procedures: Toggling, stitching

II. Abomasopexy for right dilatation or torsion
A. Right flank approach. Use caution when incising peritoneum because abomasum encroaches
B. Deflate abomasum. Massage abomasum in clockwise direction (as viewed from behind the cow), then counterclockwise direction (as viewed from right side of the cow), revealing the pylorus
C. Alternatively or during this procedure, identify caudal edge of greater omentum, proceed cranially to find duodenum, then ventrally to locate pylorus. Torsion occurs after flotation of abomasal body dorsally along abdominal wall, then counterclockwise rotation along axis of lesser omentum
D. Prior to pexy (blind procedures are inappropriate, right flank, and ventral approach laparotomies are appropriate), palpate caudal omasum for presence of left gastric artery coursing in a dorsoventral manner, to rule out concurrent omasal torsion

III. Cesarean section
A. Indications
1. Maternal fetal size mismatch
2. Transverse presentation
3. Uterine torsions
4. Schistosomus reflexus
5. Incomplete cervical dilatation

B. Approach
1. Standing left flank
2. Recumbent left flank
a. Ventral, oblique incision
b. Facilitates better visualization and exteriorization of uterus over standing approach when the uterus is not flaccid
c. Heavy sedation (e.g., xylazine, ketamine), limb and head restraint

C. Technique
1. Do not use muscle grid pattern
2. Goal is to have calves' hocks (normal presentation) resting on ventral skin incision. If not possible, have uterus exteriorized; if not possible, have uterus visible
3. Packing around uterus can minimize abdominal contamination
4. Incise uterus with scalpel, over the calf's toes, and then extend incision to hockcarpus using scissors
5. Have chains looped before incising, place over limb, hand off to producer
6. Have producer pull calf up as they pull out
7. Single layer closure, Utrecht or Cushing pattern, repeated (#3, chromic catgut, tapered needle)
8. Abdominal muscles closed in two layers

D. Therapeutic plan: Intra-abdominal lavage, parenteral antibiotics

E. Complications
1. Uterine tonus: 1 mL (1:1000) epinephrine IV is useful and safe
2. Cannot exteriorize uterus. Call for an assistant to scrub in so that uterus can be held near the incision
3. Postoperative peritonitis
4. SC abscess
5. Infertility
6. Herniation

IV. Umbilical herniorrhaphy
A. Abdominal bandaging for 3 to 6 weeks useful for simple hernias with ring less than three fingers width. Simple hernias seldom require surgical correction
B. Surgery indicated if bandaging is unsuccessful or hernial ring is large (5 fingers or greater width) or complicated with adhesions or infection
C. Vest-over pants abdominal closure is useful

V. Rumenotomy
A. Indications
1. Exploratory procedure to investigate chronic bloat
2. To relieve acute frothy bloat

B. Procedure
1. Left flank incision
2. Do not use muscle grid pattern
3. Continuous mattress pexy of rumen to skin will prevent peritoneal cavity contamination by ingesta
4. Utrecht or Cushing rumen closure (#3 chromic catgut, tapered needle) repeated

C. Complications: Postoperative peritonitis, SC abscess

VI. Castration
A. Standing or recumbent, commonly performed without anesthesia or analgesia
B. Open
1. Scrotal incision heals by second intention
2. Hemostasis preferred for greater than approximately 300 lb bodyweight; emasculator or ligation is useful

C. Closed
1. Emasculatome (Burdizzo); Crimps spermatic chord while preserving scrotal vasculature
2. Latex rings or tubing: Some added risk of tetanus

VII. Dehorning
A. No polled dairy breeds
B. Anesthesia: Local block of cornual nerve
C. Variety of methods
1. Caustic paste
a. Less than 2 months of age
b. Difficult to control distribution of paste if calf starts rubbing
2. Thermal cautery
a. Less than 3 months
b. Bloodless, hence less risk of fly strike
3. Barnes dehorner
a. 2 to 8 months
b. Variety of sizes; "scoops" horn; frontal sinus can be exposed
4. Keystone dehorner
a. More than 6 months
b. "Guillotine" like; frontal sinus will be exposed
5. Fetotomy wire
a. Usually reserved for adult cattle with long, hard horns
b. Horn can be removed at any level. Frontal sinus may be exposed

D. Postoperative management: Control of hemorrhage using cautery (heat or clotting aids) or manual retraction of vessels; protection from cold and wet environments, especially if frontal sinus is opened; topical insect repellants
E. Complications: Frontal sinusitis, blood loss anemia

ANESTHESIA

I. Local anesthesia
A. Proximal paravertebral
1. Spinal nn. T-13, L-1, and L-2
2. L1 and L2 transverse processes serve as landmarks
3. Entire flank anesthesia

B. Distal paravertebral: Similar spinal nerves approached from tips of transverse processes
C. Inverted L: Regional flank anesthesia
D. Cornual nerve: Traverses from caudal orbit to horn, just below the temporal line
E. Distal limb
1. Tourniquet
2. Venous drainage and lidocaine infusion

F. Teat
1. Ring block for skin
2. Tourniquet and local infiltration for deeper tissue

G. Epidural
 1. Caudal
 a. Sacrococcygeal or intercoccygeal
 b. Perineal anesthesia
 c. 1 mL per 100 kg body weight. Overdose can cause temporary hindlimb paralysis
 d. 2% lidocaine and/or xylazine (20 mg). Xylazine will cause sedation
 2. Cranial (lumbosacral) in calves for umbilical herniorrhaphy

H. Local infiltration

II. Sedation: Xylazine or acepromazine

III. Tranquilization: Ketamine is used, preceded by xylazine

MASTITIS

I. Introduction
 A. Often one of the most common diseases on dairy farms, and many cases result in chronic, incurable infections
 B. Clinical and subclinical manifestations: Often demanding treatment and management decisions because of the impact on cow health and milk quality
 C. Individual cow and bulk tank somatic cell count and bacterial counts are diagnostic. 250,000 cells/mL from individual cow likely indicates infection
 D. Presenting complaint may be either clinical or subclinical manifestations

II. Risk factors
 A. Environmental pathogens are generally widespread, but some can be point sourced (e.g., *E. coli* in fecal material, *Streptococcus* spp. in straw). Environmental organisms contaminate teat skin and enter around the time of milking (when the teat sphincters are open). Hence, udder preparation prior to milking is important
 B. Sources of contagious pathogens are primarily other infected cows' quarters. Parlor equipment and staff serve as fomites. When incidence is high, producers are often alerted by increases in bulk tank milk somatic cell count
 C. New infections can also occur because of milking machine malfunction, during the dry period, and in nulliparous heifers
 D. Subclinical infections of all causative organisms occur, but more commonly with gram positive and *Mycoplasma* spp. than gram negative

III. Etiology
 A. Environmental: *E. coli, Klebsiella* spp., coagulase-negative *Staphylococci* spp., *Streptococci* spp. except *S. agalactiae*
 B. Contagious: *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma* spp.

IV. Physical abnormalities
 A. Udder examination is critical (increased size, firmness, asymmetry in quarters, pain, abnormal gross milk appearance, or positive California mastitis test)
 B. Abnormal milk precedes abnormal quarter precedes abnormal cow, and the rate of progression can vary markedly depending on the organism and the cow. Milk changes may be serous, purulent, or hemorrhagic, and the udder may be necrotic
 C. Cow signs and milk changes are not predictive of organism
 D. Gangrenous quarters may indicate infection with some strains of *S. aureus*, *Clostridium* spp., and *E. coli* producing vasoactive, or other, toxins
 E. Systemic changes are those of septicemia, toxemia, dehydration, or shock: Prolonged skin tent, sunken eyes, fever (especially in acute stage), decreased or absent appetite, and ruminations, depression, and recumbency
 F. Clinical pathology can help prognosticate severe cases by measuring neutropenia and renal function, for example

V. Diagnosis
 A. Physical examination and milk culture for clinical cases
 B. California mastitis test or milk somatic cell count and milk culture for subclinical cases

VI. Complications: Chronic infection, incurable infection, permanent secretory tissue damage, pneumonia, and other organ sepsis

VII. Treatment and management
 A. Microbiological diagnosis is critical
 1. Basic microbiological procedures for identification of common pathogens should be understood
 a. MacConkey agar is selective for coliforms
 b. *Staphylococci* spp. are catalase positive
 c. *S. aureus* is coagulase positive
 2. In herd plans, calculating antimicrobial sensitivity is also prudent
 B. Many coliform infections are cleared before or shortly after milk collection, so the use of intramammary antibiotics is questioned
 1. Severe cases (with systemic signs) require parenteral broad-spectrum antibiotics on presentation (e.g., oxytetracycline) rather than after microbial diagnosis. Ancillary therapy in severe cases may include IV fluid therapy (lactated Ringer's solution or normal saline with 0.5% calcium gluconate) and antiinflammatory therapy (flunixin, aspirin, dexamethasone)
 2. Antimicrobial therapy can be safely withheld for 24 hours pending clinic or farm microbial diagnosis in cases not exhibiting systemic signs
 C. Environmental gram-positive infections causing clinical signs should be treated with the intramammary antibiotics that the herd minimal inhibitory concentration (MIC) survey establishes may be effective
 D. *Mycoplasma* spp. infections are incurable and infected cattle should be removed from the herd
 E. Many *S. aureus* infections are refractory to antimicrobial therapy, especially at label doses
 F. *S. agalactiae* infections respond well to antimicrobial therapy

VIII. Prognosis is variable, from acute fatality, grossly normal milk but persistent infection, to complete return to normal function and clearance of organisms. Many organisms have different prognoses from case to case

MUSCULOSKELETAL SYSTEM DISEASE

I. Digital
 A. Introduction
 1. Lameness is often one of the most common diseases on dairy farms and most commonly presents in the hindlimb (lateral claw)
 2. Many hoof diseases have multifactorial causes
 B. Skin disease
 1. Footrot
 a. Also known as interdigital phlegmon, interdigital necrobacillosis, foul in the foot
 b. Opportunistic infection with *Fusobacterium necrophorum*. Usually seen with poor environments that lead to skin immunocompromise or pathogen buildup, such as wet, muddy conditions. Any conditions that lead to abrasion between claws increase risk of foot rot
 c. Pathognomonic fetid smell and necrotic appearance. Also swelling up to fetlock and early fever
 d. Parenteral procaine penicillin G, ceftiofur, or oxytetracycline
 e. Prevention: Reduce exposure to environments that are constantly wet and/or abbrasive to the interdigital space.
 2. Hairy heel warts
 a. Also known as digital dermatitis, papillomatous digital dermatitis, foot warts, strawberry warts
 b. Cause not well established, but not viral, and probably bacterial of the genus *Treponema*
 c. Often interdigital skin at heel, can be elsewhere around coronary band. Pathognomonic appearance, papillomatous, red when cleaned (similar to surface of strawberry), with long hairs around circumference
 d. Respond well to topical or parenteral oxytetracycline
 e. Use of oxytetracycline or copper sulfate foot baths can control this disease
 f. Innate immunity develops, so more common in nulliparous heifers
 g. Contagious disease
 3. Interdigital fibroma: A mass of connective tissue that grows in the interdigital space, of largely unknown cause, but theorized to be associated with chronic inflammation Sometimes causes lameness, when surface becomes excoriated or mass bears weight, but often subclinical. Usually multiparous cattle are affected. Treated by excision
 C. Hoof disease
 1. Laminitis
 a. Rarely presents as in horse with acute and severe multi-limb lameness. This form is most commonly seen in feedlot cattle on high-energy rations or in individual cattle when acutely exposed to high-energy diets or follow acute and severe bacterial infection in another organ system
 b. Checks in hoof growth or growth of abnormal horn result in secondary diseases, which can present as lameness (e.g., white-line separation, sole abscess, sole ulceration, soft and thin soles, wall cracks, or misshaped hooves, e.g., corkscrew claw)
 c. Cause is multifactorial
 (1) Rumen fermentation (subacute rumen acidosis)
 (2) Toxemia (e.g., metritis, mastitis)
 (3) Environmental (e.g., impact trauma from walking surface)
 (4) Misshapen hooves (can lead to laminitis *and* is caused by laminitis)
 2. Sole abscess
 a. Present with variable separation of white line, which on exploration tracks to a pressurized pocket of purulent material (classic signs), dead space, or potential space between old sole and new sole, into corium, or up the wall, possibly to a point of release (somewhere on coronary band)
 b. Cause is multifactorial, as white-line integrity is compromised by many factors
 (1) Misshapen hooves
 (2) Subclinical laminitis
 (3) Physical trauma (e.g., stone penetration)
 (4) Physical horn changes (e.g., maceration, bacterial decay)
 c. Mixed flora, including gram-negative anaerobes
 d. Treated by drainage, physical protection of exposed corium by applying supportive block elevation to contralateral sound claw, and parenteral antibiotic therapy if corium is infected. Most cases have excellent prognosis
 e. Severe coriitis rarely ensues but can lead to osteomyelitis, septic arthritis, and tenosynovitis, all surgical conditions with grave prognoses
 3. Sole ulcer
 a. Also known as Rusterholtz ulcer
 b. Pathognomonic location, at corium covering flexor tuberosity of distal phalanx
 c. Present with horn erosion at heel-sole junction, which on removal exposes corium, sometimes covered with a granulation bed
 d. Cause is multifactorial
 (1) Subclinical laminitis, with pedal rotation
 (2) Misshapen hooves, causing increased force applied to heel during locomotion
 (3) Lack of cushion on walking surface
 e. Treatment involves horn removal around ulcer, exposure, and removal of granulation bed and application of supportive block to sound contralateral claw. Guarded prognosis for recovery, fair to good prognosis for functional improvement, provided hoof is reexamined frequently to repeat treatment, and no complications exist
 f. Complications include deep digital flexor tenosynovitis and osteomyelitis,

retroarticular abscessation, surgical conditions with grave prognoses

II. Upper limb
 A. Hip luxation
 1. Common after adductor muscle trauma in adult cows
 2. Ventral or dorsal luxation: Rectal and pelvic examination may locate the displaced femoral head
 3. Manual reduction under heavy sedation or preferably anesthesia and muscle relaxation
 4. Grave prognosis; poor if reduced within several hours
 B. Anterior cruciate rupture
 1. Uncommon
 2. Anterior drawer sign may be elicited
 3. Slaughter or euthanasia is recommended
 C. Septic carpitis of cows
 1. Common after falls and struggling on cement
 2. Begins as skin abrasions and progress to joint involvement
 3. Preventive measures include improving concrete traction with straw or sand for recumbent cows and wound care for carpal abrasions. Prophylactic antibiotic use should be considered
 4. Once the joint becomes involved, prognosis is grave. Repeated lavage is important, but this is difficult to implement in the field
 D. Septic arthritis of calves
 1. Common in cases of omphalitis; also enteritis and pneumonia. Can present without other systems affected.
 2. Often polyarthritis
 3. Mixed flora (e.g., coliforms, gram-negative anaerobes, *Streptococci* spp., *Mycoplasma* spp.) can cause arthritis without other signs, most commonly in feedlot cattle
 4. *Mycoplasma* spp.
 5. Clinical signs: Swelling, pain, fever, recumbency
 6. Prognosis is guarded when treatment initiated in acute stage and a long course of broad-spectrum antibiotics is administered. Prognosis is grave if treatment is initiated in chronic stage. Repeated lavage improves prognosis, but this is difficult to achieve in the field

III. Muscle disease
 A. Hypocalcemia (milk fever)
 1. Jersey breed very susceptible
 2. Clinical signs become more severe as serum calcium concentration falls
 a. First, subclinical changes in smooth muscle tone
 (1) Uterine involution
 (2) Rumen, abomasum contraction
 b. Skeletal muscles become increasingly weak, leading to recumbency
 c. Signalment is diagnostic: Usually day before, day of, or day after calving; multiparous
 3. Cause: Sudden increase in calcium requirements with commencement of lactogenesis
 4. Treatment: Calcium gluconate, IV or SC (depending on severity of signs)
 5. Prevention: Dietary acidification for the 3 weeks before calving, by feeding anionic salts (e.g., NH_3Cl, $MgCl_2$, $[NH_3]_2SO4$, $MgSO_4$ or HCl treated concentrates), has many endocrine effects, one of several useful ones being improved PTH receptor function
 6. Compliance: Monitor urine pH (normal = 8.0, goal = 5.5 to 6.5)
 B. Grass tetany
 1. Cause: Grazing of forages low in magnesium
 a. Usually seen when grazing succulent, immature grasses, or cereal grains. Rare with legumes
 b. More common in adult cows (inability to mobilize magnesium from bones)
 2. Pathophysiology: Hypomagnesemia
 3. Clinical signs: Uncoordinated gait, recumbency, convulsions, coma
 4. Treatment and control
 a. IV injection of magnesium borogluconate
 b. Magnesium supplied on a daily basis when tetany-prone conditions exist
 C. Clostridial myonecrosis
 1. Often following injections or trauma (including birthing). Spores may become vegetative in muscle after bruising. Generally a disease of young stock (less than 2 years of age). Grave prognosis
 2. Clinical signs: Inflammation of muscle bodies, often in gluteal muscles and perineal area, sometimes with SC crepitus and skin discoloration and cooling. Signs of toxemia and shock develop quickly
 3. Causes: *Clostridium chauvoei, (blackleg) C. septicum (malignant edema), C. sordelli* (major)*, C. novyi* type B, *C. perfringens* type A, *C. carnis.* (minor)
 4. Treatment: Parenteral or local procaine penicillin G; surgical debridement and fenestration; supportive care
 5. Prevention: Vaccination
 D. Downer cow syndrome
 1. Term applied to otherwise healthy recumbent cattle when no other problems can be identified
 2. Occurs after treatment of some cases of any disease that leads to recumbency, such as milk fever, mastitis, and severe lameness, and also following trauma such as slipping and falling on cement
 3. Recumbency leads to secondary changes, which are responsible for the lack of response to the primary disease, including myonecrosis, peripheral neuropathy (e.g., peroneal nerve), and hip luxation. This develops within 6 to 12 hours of recumbency. Other problems, such as mastitis and skin trauma, often over the carpi, may occur because of the recumbency
 4. Muscle necrosis can be quantified with serum creatine kinase (CK) and aspartate aminotransferase (AST) measurement. These are positively correlated with extent of myonecrosis and help predict prognosis
 5. Treatment: The mainstay to treatment is physical therapy, such as hoisting, massage, rolling, and deep bedding. Nonsteroidal antiinflammatory

drugs (NSAIDs) are useful. Convalescence is long, and prognosis for full recovery is often grave

REPRODUCTIVE SYSTEM DISEASE

I. Cow infertility
 A. Failure to conceive is a very common problem in lactating dairy cows, and often the cause cannot be determined
 B. Risk factors include infectious agents (e.g., BVDV, *Leptospira borgpetersenii serovar hardjo*), nutrition (e.g., over feeding of protein malnourishment), and environment (e.g., heat stress)
 C. Venereal disease
 1. *Campylobacter fetus* (bovine campylobacteriosis, vibriosis)
 a. Characterized primarily by early embryonic death, infertility, a protracted calving season, and occasionally abortion
 b. Bulls generally act as a mechanical vector of the organism by carrying the organism from one cow to another
 c. Infected bulls are asymptomatic and produce normal semen
 d. Collecting mucus samples from the vagina for culture is the best way of confirming the disease
 e. Campylobacteriosis in the female can be effectively prevented by vaccination
 2. *Tritrichomonas fetus* (bovine trichomoniasis)
 a. Flagellated protozoa
 b. Characterized by a period of pronounced infertility following natural breeding
 c. Infected herds experience decreases in calving percentage and delayed calving
 d. Infection in the cow occurs primarily through natural service with an infected bull
 e. In bulls, *T. foetus* lives in the crypts of the penis and the sheath
 f. Infections may result in small quantities of a mucopurulent vaginal discharge within a few weeks of breeding
 g. The infected cow will conceive, but death of the fetus occurs most commonly between 7 to 10 weeks of gestation
 h. The infected cow will usually remain infertile for 2 to 6 months
 i. Diagnosis: In the bull involves collecting a sample from the prepuce for culture
 j. Control and prevention: Bull testing. Purchase of virgin bulls. Avoiding sharing or leasing of mature bulls. Vaccination is available but does not prevent herd infection

II. Bull infertility
 A. Congenital
 1. Testicular hypoplasia
 2. Short penis
 3. Persistent penile frenulum
 4. Short retractor penis
 5. Rainbow or corkscrew penis
 B. Acquired
 1. Fibropapilloma (penile wart)
 2. Penile hematoma
 3. Preputial hematoma
 4. Seminal vesiculitis (*Arcanobacter pyogenes*)
 5. Testicular degeneration from orchitis, fever, aging, scrotal frostbite, trauma, excessive scrotal fat, stress, poor nutrition
 6. Structural problem (e.g., lameness, blindness)
 7. Decreased libido: Diagnosed with breeding soundness examination

III. Early embryonic death
 A. It is commonly recognized that many cows diagnosed as not pregnant at pregnancy testing were in fact pregnant at one time (e.g., less than 45 days post insemination)
 B. This is diagnosed more often as gestational age of initial pregnancy test decreases, such as occurs when a herd switches from manual rectal palpation (35 days' gestation) to rectal ultrasound (28 days' gestation)
 C. Mechanisms are not fully understood; risk factors include exposure to some infectious diseases, embryo abnormalities, and the dam's endocrine function (e.g., progesterone concentration during early pregnancy)

IV. Retained placenta
 A. Normally expelled within 12 to 24 hours of calving
 B. Very common disease in dairy cattle
 C. Pathophysiology is not completely understood but thought to involve immune system dysfunction
 D. Risk factors include multiple birthings, dystocia, induction of parturition, and nutritional deficiencies (e.g., energy, vitamin E, selenium)
 E. Cotyledonary placentation prevents complete manual extraction; therefore, this is controversial. There are no effective therapies
 F. This is a common risk factor for metritis

V. Puerperal metritis
 A. Case definition is important because concurrent signs to uterine infection vary dramatically and descriptions vary by author. Here, puerperal metritis has systemic signs, with chronic localized uterine infection (endometritis) as a sequela
 B. Clinical signs: History of fever, retained placenta, dystocia, birth of multiples. Signs are impaired rumen motility, inappetance or anorexia, dehydration, fetid smelling, hemorrhagic vaginal discharge, abnormalities in uterine tone, size, and wall thickness
 C. Causes: Mixed flora, including *Fusobacterium necrophorum, Arcanobacterium pyogenes, clostridial* spp., coliforms, and *streptococci* spp. Introduced either during calving (e.g., during vaginal examination) or ascend from the labia and vagina owing to immunocompromise (e.g., retained placenta, vaginal trauma)
 D. Treatment: Parenteral antibiotics (tetracyclines or β-lactam antibiotics). Local antibiotic infusion and removal of placenta is controversial. NSAIDs control uterine inflammation
 E. Complications: Perimetritis (leading to peritonitis and adhesions to other viscera or abdominal wall), pyometra, or endometritis (no systemic signs), cream-colored vaginal discharge (*A. pyogenes*) which usually resolves after estrus, delayed conception, ascending urinary tract infections, left displaced abomasa. Vaginal abscesses and fistulous tracts may occur secondary to vaginal trauma

VI. Abortion
 A. Numerous causes, such as *Campylobacter fetus*, *Tritrichomonas fetus*, BVDV, IBR, *Neospora canis*, leptospirosis, *Arcanobacter pyogenes*, listeriosis, *Histopilus somnus*, *Brucella bovis*, *Salmonella* Spp., trauma, fetal and placental anomalies, inflammatory disease in other organ systems (PGF2 alpha production), maternal stress (elevation in blood cortisol concentrations), and nutritional problems (e.g., exposure to fungi)
 B. Acceptable (dairy) herd rates are below 10% of pregnancies (45 days to term) per year
 C. Diagnostic samples include fresh fetus, placenta, and blood from dam (at abortion and 3 weeks later)
 1. No causative agent found in most cases
 2. Cost-effectiveness is questioned if incidence is acceptable
 D. Rising serum antibody titer to most infectious agents is suggestive of cause
 E. Some tissues are more useful than others for specific diseases: Fetal brain and heart for histopathological diagnosis of neosporosis; placenta for histopathological and microbiological diagnosis of mycotic abortion

VII. Anestrus
 A. Common risk factors include chronic diseases such as lameness and malnourishment. Differential diagnoses include unobserved estrus, pregnancy, pyometra
 B. Clinical signs: Absence of estrus, small reproductive organs, flaccid uterus
 C. Treatment: Correction of underlying problem is the most successful intervention, but progesterone controlled intravaginal releasing devices are also useful

VIII. Cystic ovaries
 A. Diagnosed by palpation of structures greater than 1 inch in diameter on ovary
 B. Ultrasound or progesterone assays aid in distinguishing follicular cysts from luteal cysts
 C. Cause is unknown
 D. Clinical signs: No signs, anestrus, or nymphomania
 E. Treatment: GnRH then prostaglandin, given 2 weeks apart. Some regress spontaneously

IX. Uterine prolapse
 A. Risk factors include prolonged, strenuous labor, large calf, hypocalcemia
 B. Treatment: Replacement by manual manipulation. Extend the hindlimbs behind sternally recumbent cows to tilt pelvis. Caudal epidural will aid in replacement. Ensure that entire horn is replaced; this may require extension of reach by use of a tool such as a plastic bottle. Vaginal pursestring or mattress sutures, placed with Buhner needle, may prevent recurrence
 C. Complications include pre- or post-manipulation uterine trauma, for which repair or amputation may be indicated, uterine vessel thrombosis or rupture, and recurrence (hours to days)

X. Congenital abnormalities
 A. Cerebellar hypoplasia (BVDV)
 B. Arthrogryposis
 1. Lupines
 2. Autosomal recessive inheritance
 C. Hypotrichosis (autosomal recessive inheritance)
 D. Pulmonary hypoplasia with anasarca (PHA, autosomal recessive inheritance)
 E. Tibial hemimellia (autosomal recessive inheritance)
 F. Breed specific abnormalities (e.g., curly coat in Angus)

XI. Dystocia
 A. Normal presentation is anterior, dorsosacral, with extended forelimbs
 B. Caudal epidural is a useful aid to vaginal examinations and fetal repositioning but will not stop uterine contractions because of the Ferguson reflex. Does alleviate some abdominal straining and provides caudal anesthesia
 C. Embryotomy (fetotomy) is useful for vaginal delivery of dead or necrotic fetuses
 D. Cesarean section can be successful in cows early in labor. They are less successful when the fetus is dead, uterus is inflamed, or uterus cannot be exteriorized from the abdominal cavity
 E. Preventing fecal contamination to the vagina during examination is important
 F. Breed specific abnormalities (e.g., curly coat in Angus)
 F. Fetal-maternal disproportion: Choose between vaginal delivery and cesarean section, depending on estimate of fetal and maternal sizes. Lubrication is useful. Slow vaginal delivery can successfully dilate vaginal vestibule
 G. Malpresentation
 1. Lateral displacement of the head: Epidural, retraction using snare or eyehooks
 2. Carpal and shoulder flexion: Epidural, repulsion, and extension
 3. Breech: Epidural, repulsion, and extension
 4. Posterior: Cannot be corrected and should be delivered vaginally in this position
 5. Simultaneous multiple presentations: Epidural, examination, and repulsion of one of the fetuses
 H. Fetal pathology
 1. Congenital abnormalities
 a. PHA
 b. Arthrogryposis: Fetotomy or cesarean section
 c. Fetal ascites: Drain the fetal abdomen before delivery
 d. Schistosomus reflexus: Cesarean section
 2. Fetal death
 a. Mummy: Many are expelled after naturally occurring or induced estrus. Cesarean section required for those that aren't when cervix remains closed. Partial cervical dilation allows embryotomy
 b. Emphysematous fetus: Embryotomy, sometimes protracted over several days and with supportive care of the dam, or caesarean section
 I. Uterine pathology
 1. Uterine torsion: Extent of detorsion varies. Most mild can be before labor and without affecting reproductive viability; most severe can present during labor with complete

ischemic necrosis of uterus or ovaries. Detorsion is attempted by rolling the cow, the calf (by hand or using a detorsion bar), or uterus (during a laparotomy). Cervix is often not dilated and often does not progressively dilate after detorsion, for which a cesarean section is indicated
2. Uterine atony: Risk factors are hypocalcemia and flunixin

XII. Vaginal prolapse
- A. Risk factors include breed (Hereford, *Bos indicus*), familial incidence, previous occurrence, body condition (fat), and age (multiparous)
- B. Usually occur in final trimester of gestation
- C. Cervical function may be impaired, so labor should be observed closely
- D. Treatment: Replacement by manual manipulation. Caudal epidural will aid in replaceent. Vaginal pursestring or mattress sutures, placed with Buhner needle, may prevent recurrence. Transvaginal placement of pins across dorsal pelvic musculature will also prevent recurrence

XIII. Brucellosis (Bang's disease in cattle)
- A. Zoonotic bacterial disease of caused by *Brucella abortus*
- B. In humans, causes undulant fever
- C. Found most commonly in cattle, buffalo, and bison
- D. Transmission
 1. Transmitted between animals by contact with the placenta, fetus, fetal fluids, and vaginal discharges from an infected animal
 2. Can be spread on fomites including feed and water
 3. In conditions of high humidity, low temperatures, and no sunlight, these organisms can remain viable for several months in water, aborted fetuses, manure, wool, hay, equipment, and clothes
- E. Clinical signs
 1. Infections in nonpregnant females are usually asymptomatic
 2. In pregnant cows, abortions, stillbirths, and weak calves are most common manifestations
 3. In bulls, epididymitis, seminal vesiculitis, orchitis, and testicular abscesses
 4. Systemic signs do not usually occur in uncomplicated infections, and deaths are rare except in the fetus or newborn
- F. Diagnosis: Clinical signs consisting of abortion storms, serology, culture
- G. Control and prevention: New additions from brucellosis-free farms or regions of the country; vaccination

XIV. Pregnancy diagnosis is often by rectal palpation
- A. Cardinal signs
 1. Fetus
 a. Babies rattle sensation circa 60 days
 b. Skeletal components last trimester
 2. Placentomes
 a. Pea size circa 70 days
 b. Silver dollar size in last trimester
 3. Chorioallantoic (membrane) slip: Most useful 35 to 75 days
 4. Amniotic vesicle: Palpable 32 to 60 days
 a. Pea = 35 days
 b. Pinky finger diameter = 40 days
 c. Small hens egg = 50 days
 d. Turkey egg = 60 days
- B. Secondary signs
 1. Middle uterine artery diameter and fremitus
 a. Large and with fremitus on gravid side after circa 4 months
 b. Also occurs with recent abortion, recent calving, and metritis
 2. Uterine position: Within abdomen after 60 days
 3. Uterine size and weight

GASTROINTESTINAL SYSTEM DISEASE

I. Wooden tongue (actinobacillosis)
- A. Chronic granulomatous infection with *Actinobacillus lignieresi* in the tongue of ruminants (normal flora)
- B. Diagnosis typically made by characterization of tissue growth and firmness to palpation
- C. Poor response to antimicrobial therapy, but attempts in recent infections with sodium iodide or penicillin are appropriate

II. Lumpy jaw (actinomycosis)
- A. Chronic granulomatous infection with *Actinomyces bovis* in the mandible of ruminants (normal flora) (Figure 49-1)
- B. Diagnosis typically made by characterization of tissue growth and firmness to palpation
- C. Poor response to antimicrobial therapy, but attempts in recent infections with sodium iodide or penicillin are appropriate

III. Mucosal disease
- A. Mucosal disease is a rare and usually fatal clinical syndrome seen only in cattle that are persistently infected (PI) with BVDV
- B. Mucosal disease occurs when PI cattle, which are infected with noncytopathic BVDV, become superinfected with cytopathic BVDV
- C. Source of cytopathic BVDV may include the following:

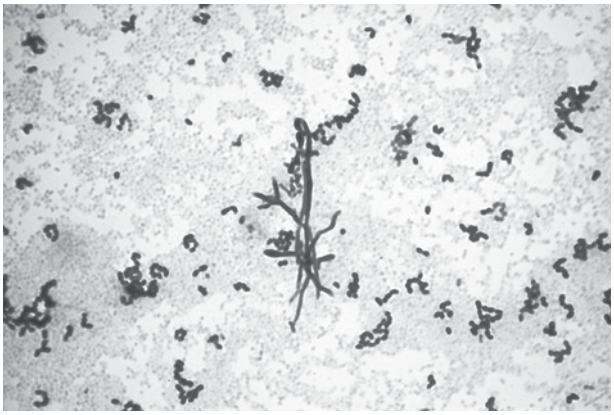


Figure 49-1 Gram stain of aspirate from lumpy jaw lesion. Gram-positive branching filamentous rods are characteristic of *Actinomyces bovis*. (From Divers TJ. *Rebhun's Diseases of Dairy Cattle*, 2nd ed. St Louis, 2007, Saunders.)

1. Mutation of resident persistent noncytopathic virus
2. Horizontal virus transmission from other cattle
3. Live vaccines containing cytopathic virus

D. Cytopathic virus must be closely related antigenically to the persistent noncytopathic virus

E. Clinical signs
1. Clinical course ranges from 3 days to several weeks
2. Anorexia, depression
3. Diarrhea, often bloody
4. Mucosal vesicles and erosion involving the nares, muzzle, mouth, esophagus, and small intestine (especially in areas of lymphoid aggregates, i.e., Peyer's patches)

F. Diagnosis: Clinical signs, gross pathology, virus isolation of both noncytopathic and cytopathic BVDV strains

IV. Malignant catarrhal fever

A. Sporadic and highly fatal disease of cattle and other ruminants

B. Etiology: Either of two gamma-herpes viruses
1. Alcelaphine herpesvirus-1 (AHV-1), carried by wildebeest
2. Ovine herpesvirus-2 (OvHV-2 or OHV-2), carried by sheep and goats

C. Transmission: The exact mode of transmission is unknown, but close contact between susceptible species (i.e., cattle) and carrier species (i.e., sheep or wildebeest) is necessary. Cattle-to-cattle transmission is rare

D. Clinical signs
1. Sudden death may occur preceded by 12 to 24 hours of depression, diarrhea, and dyspnea
2. Fever (105° to 107° F) and inappetence
3. Bilateral corneal opacity that begins at the corneoscleral junction
4. Serous to mucopurulent discharges from the eyes and nose
5. The muzzle and nares are usually encrusted
6. Dyspnea, open-mouth breathing
7. Ptyalorrhea
8. The oral mucosa is often hyperemic and may contain multifocal or diffuse areas of necrosis
9. The skin is sometimes ulcerated, and hardened scabs may develop on the perineum, udder, and teats
10. The horn and hoof coverings may slough
11. Joints may be swollen
12. Superficial lymph nodes may be enlarged

E. Pathology: Epithelial necrosis in the GI, respiratory, and urinary tracts; lymphoproliferation; interstitial infiltration of nonlymphoid tissues by lymphoid cells; and vasculitis

F. Diagnosis
1. Malignant catarrhal fever should be suspected in susceptible animals with the characteristic clinical signs, especially if they have been in contact with sheep, goats, or wildebeest
2. Polymerase chain reaction (PCR) can detect both AHV-1 and OHV-2 viral DNA

G. Control and prevention
1. In outbreaks, separation of susceptible species from sheep and goats (OHV-2) or wild ruminants (AHV-1) will contain transmission
2. Virus is susceptible to commonly used disinfectants

V. Choke

A. Most commonly foreign body–related (e.g., apple, potato) but can also be a feed impaction

B. Clinical signs: Ptyalorrhea, bloat

C. Treatment: Manual extraction under sedation and restraint, lubrication and lavage, or rumenotomy

VI. Forestomachs

A. Bloat
1. Overview
a. Rumen distension can be categorized as acute or chronic, gassy, or frothy
b. Acute: Determined from history and rapid progression of clinical signs; often frothy bloat
c. Chronic: Determined from history and slow progression of clinical signs. Often free gas. Cause is often unable to be determined
2. Causes
a. Acute, gassy is due to esophageal foreign body
b. Acute, frothy
(1) Legume over-ingestion, grain overingestion
(2) Rumen or reticular foreign body (e.g., baling twine)
c. Chronic is due to vagal neuropathy (e.g., previous pleuritis, peritonitis), rumenitis, reticular abscess or neoplasia, rumen or reticular foreign body (e.g., baling twine), obstruction of reticulo-omasal orifice (e.g., placenta), abomasal impaction (e.g., sand), thoracic esophageal compression (e.g.,lymphadenomegaly)
3. Diagnosis
a. Bloat is obvious on physical examination, but determining type can be more difficult (Figure 49-2)
b. Orogastric intubation: Insensitive test for gassy bloat because of position of lower

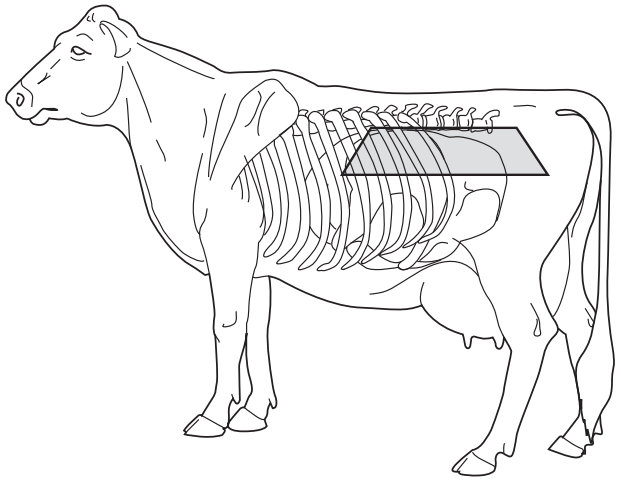


Figure 49-2 Rumen distention (left side). Area of tympanic resonance (shaded) heard with ruminal tympany. (From Fubini S, Ducharme N. *Farm Animal Surgery*. St Louis, 2004, Saunders.)

esophageal sphincter-cardia, relative to rumen ingesta. Froth will not pass through most tubes
c. Exploratory laparotomy and rumenotomy
4. Treatment
a. Orogastric intubation
b. Rumen administration of surfactants
c. Exploratory laparotomy and rumenotomy and appropriate interventions (e.g., removal of rumen foreign body)
d. Rumen fistulation (e.g., bloat whistle)
5. Prognosis is good unless chronic, and cause is not known

B. Traumatic reticuloperitonitis
1. Overview
a. Incidence is often low in well-managed herds until a harvest accident occurs, such as chopping of fence wire with forages
b. Common in herds where crop fields are littered
c. Incidence is reduced by placement of reticular magnets at young age (not effective against aluminum)
2. Pathophysiology: Progression varies by case
a. Sharp, linear, metallic foreign body is ingested
b. Inflames reticular mucosa
c. Penetrates reticular wall
d. Focal peritonitis
e. Migrates to pericardial sac
f. Vagal nerve disease can occur after any stage
3. Clinical signs vary by progression: Inappetance, changes in rumen motility, bloat, fever, severe abdominal pain (lateral recumbency, arched back posture), respiratory changes (tachypnea, dyspnea, harsh lung sounds), cardiac changes (arrhythmia, pericardial splash)
4. Diagnosis: Often postmortem; exploratory laparotomy and rumenotomy
5. Management: Animals with peritoneal or thoracic involvement will be condemned at slaughter so euthanasia is recommended. Otherwise, removal of foreign body is recommended

C. Grain overload
1. Pathophysiology: Lactic acidosis secondary to acute overingestion of concentrate, particularly those fermented quickly, such as small grain cereals. Hyperosmolar environment draws body water into rumen. Animals develop metabolic acidosis and hypovolemic shock. Causes chemical rumenitis, which can lead to vagal nerve dysfunction, hepatic miliary abscesses, and vena caval syndrome
2. Clinical signs: Dehydration, depression, ventrally distended rumen, rumen atony, diarrhea
3. Diagnosis: History and rumen pH (less than 5.0)
4. Treatment: IV 1.3% $NaHCO_3$, oral $NaHCO_3$, rumen lavage by Kingman tube or rumenotomy in valuable cattle. Broad-spectrum antibiotics (e.g., oxytetracycline, sulfadimethoxine). NSAIDs
5. Prognosis: Grave for cattle with most severe signs, guarded for others. Laminitis may ensue

VII. Abomasal

A. Ulceration
1. Causes: Largely unknown, but lymphosarcoma in the abomasal wall can ulcerate the mucosa. Commonly associated with abomasal displacement and chronic, painful diseases such as lameness
2. Pathophysiology: Variable, from mild subclinical mucosal ulceration, mucosal hemorrhage leading to anemia or perforation and peritonitis
3. Clinical signs: Melena, anemia, and impaired rumination
4. Treatment: Symptomatic (oral MgO, $NaHCO_3$), prophylactic antibiotics. Cattle do not have abomasal histamine receptors; oral omeprazole is not efficacious

B. Displacement
1. Cause is poorly understood. Common risk factors for left displacement are dietary changes, often associated with improper feeding of fiber, presence of other diseases, such as puerperal metritis and birth of multiples. Volatile fatty acids within the abomasum and hypocalcemia negatively affect motility and are associated with common risk factors. Gas production from microbial fermentation and CO_2 from HCl reaction with dietary bases cause dilatation. Abdominal voids created by sudden changes in uterine and rumen size may be involved. Left displacements are usually in the first 30 days of lactation,
2. Pathophysiology
a. Left displacements cause a partial obstruction to the flow of ingesta. HCl accumulates in the abomasum, leading to mild hypochloremia and metabolic alkalosis. Appetite is impaired, leading to secondary ketosis
b. Right displacements begin as dilatations, with dorsal displacement, then sometimes torse. Extent of hypochloremia and metabolic alkalosis increases when torsion occurs. Ischemic necrosis and severe dilatation after torsion can compromise abomasal integrity, including vagal nerve. Rumen atony may develop postoperatively in these cases because of vagal nerve dysfunction

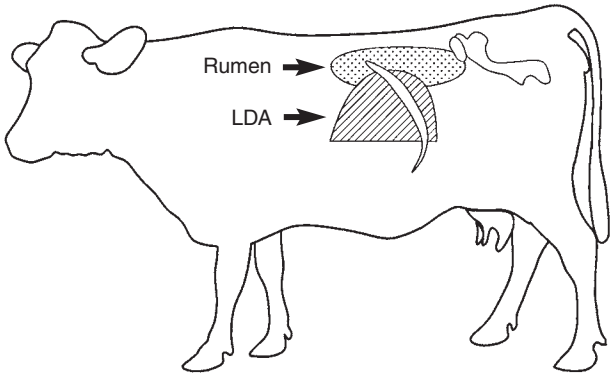


Figure 49-3 Schematic representation of the area of the gas ping percussed in association with a left displaced abomasum (LDA) or gas ping in the rumen. (From Smith BP. *Large Animal Inter nal Medicine*, 4th ed. St Louis, 2001, Mosby.)

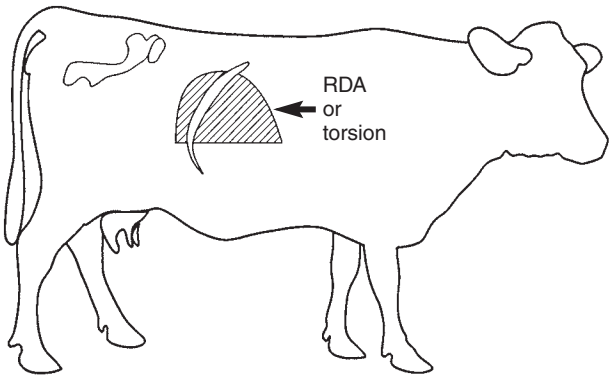


Figure 49-4 Schematic representation of the area of the gas ping percussed in association with a right displaced abomasum (RDA) or abomasal torsion. (From Smith BP. *Large Animal Internal Medicine*, 4th ed. St Louis, 2009, Mosby.)

3. Clinical signs: Left displacement; characteristic ping mid-left abdomen; diarrhea is common (normal color, water consistency with clumps of undigested fiber material), ketonuria. Right dilatations and displacements have similar signs to left except ping to the right. Right abomasal torsions; tachycardia, right abdominal distension, dehydration, depression, weakness (Figures 49-3 and 49-4**)**
4. Treatment: Surgical diseases. IV isotonic or hypertonic (7.2%) NaCl if moderately or severely dehydrated or hypochloremic
5. Prognosis: Excellent except for right torsions (guarded to grave)
6. Complications
 a. Recurrence is rare
 b. Ulceration is common with left displacement, before or after diagnosis is made
 c. Vagal nerve disease is common after severe right dilatation and torsion
 d. Omasal torsion with right abomasal torsion

C. Impaction
1. Often diagnosed intraoperatively during repair of left displaced abomasa or suspected when cow has nonspecific and mild GI dysfunction, and sand is palpable in feces
2. Cause: Sand ingestion (true pica, or accidental ingestion of small quantities among forages, over a long time), abomasal displacement, vagal nerve disease. Sand is readily accessible to cows on farms which bed with it. Pica may be associated with severe pain or discomfort, or nutritional deficiency
3. Pathophysiology: Not fully understood, but pica is believed to lead to accumulation proximal to the pyloric sphincter. Abomasal displacement may exacerbate accumulation of sand or fibrous ingesta. Also, impactions may predispose to displacement. Vagal nerve dysfunction can cause pyloric outflow failure
4. Clinical signs: Inappetance, dehydration, sand or gravel in feces, focal, mobile pings on right abdomen, ping mid left abdomen with left abomasal displacement
5. Treatment: Intraoperative massage, oral purgatives (e.g., mineral oil), rehydration
6. Prognosis is guarded to good

VIII. Intestinal

A. Johne's disease
1. One of the most important infectious diseases affecting the cattle industries because it has significant negative effects on production, is incurable, and all tests for the disease are insensitive
2. Cause: *Mycobacterium avium* subspecies *paratuberculosis*. Transmission is largely feco-oral, although the organism is shed in colostrum and milk, and there is some vertical transmission
3. Pathophysiology: Chronic, subclinical infection, acquired before rumen development, leading to granulomatous enteritis in ileum, often years later, causing malabsorption and protein loss, weight loss, and hypoproteinemia
4. Clinical signs: Emaciation, normal appetite, voluminous and water consistency feces, dependent edema if hypoproteinemic (e.g., submandibular)
5. Diagnosis: Serum ELISA, fecal culture, both insensitive (30% to 50%) in subclinical stages
6. Management: Because the disease is incurable, serial testing, differential management of test-positive cows, and prevention of new infections are important. Preventative measures include separation of calves from dams soon after birth, feeding of colostrum only from test-negative cows, isolation of subclinical cases at the time of calving, and prompt removal of clinical cases from the herd

B. Salmonellosis
1. Common contagious enteric disease of cattle of all ages
2. Causes: Multiple *Salmonella* spp. (e.g., *S. typhimurium, S. dublin*). Symptoms vary by host immunity and organism virulence
3. Pathophysiology: Gastroenteritis affecting abomasum to rectum, but seldom all. Dehydration, sepsis, and toxemia may ensue. Subclinical infections are common
4. Clinical signs: Diarrhea, often yellow, water consistency, with mucous, mucosa, or fresh blood. Fever is common. Calves can present with signs of pneumonia before signs of sepsis or enteritis. *(S. dublin)* Systemic changes are those of septicemia, toxemia, dehydration, or shock: Prolonged skin tent, sunken eyes, decreased or absent appetite, ruminations, depression, and recumbency
5. Treatment: IV and oral fluid therapy (IV isotonic NaCl or $NaHCO_3$ can be manufactured and given in the field, KCl can be given orally or added to IV infusions); broad-spectrum antibiotics are indicated if sepsis is suspected, also NSAIDs
6. Diagnosis: Laboratory confirmation by fecal culture is recommended, with minimum inhibitory concentrations for antibiotics measured
7. Management: Identification of subclinical cases and differential management or removal (by serological methods or serial fecal culture)

may be indicated if incidence of clinical cases is high. Efficacy of bacterins is questionable. Common-sense biosecurity measures on farm, including measures to prevent zoonoses, are imperative

C. Other adult bovine diarrhea
 1. Diet-induced: Control with gradual acclimation to new diets, monitoring and adjusting of ration components
 2. BVDV: Control with identification and elimination of BVDV PI cattle and vaccination

D. Jejunal hemorrhagic syndrome (hemorrhagic bowel syndrome, HBS)
 1. Relatively new disease on dairy farms
 2. Cause is unknown, but *Clostridium perfringens* type A and *Aspergillus fumigatus* have been implicated
 3. Acute, localized, necrotizing, hemorrhagic enteritis leading to obstruction
 4. Clinical signs include acute death or signs of small intestinal obstruction, secondary fluid and electrolyte changes, and rapid progression to moribund state. Fecal material scant or absent; can be black-red and jelly-like if blood is present
 5. Surgical resection is warranted if obstructed, but carries grave prognosis. Procaine penicillin G is recommended because *C. perfringens* is implicated

E. Cecal dilatation and volvulus
 1. Uncommon condition in which production and appetite decrease and cecum is distended Note that cecal gas is also a normal finding in some normal cattle (Figure 49-5)
 2. Cause and pathophysiology are poorly understood but probably related to bacterial fermentation in the cecum
 3. Treatment includes supportive care (e.g., fluid therapy and analgesics) and surgical intervention (typhlotomy, drainage, and detorsion) if clinical signs or response to therapy warrant

F. Suckling calf scours
 1. Cause
 a. Age of calf can be useful
 (1) 1 to 5 days: *E. coli*
 (2) 5 to 14 days: Rotavirus, coronavirus
 (3) 10 to 30 days: *Cryptosporidium parvum*
 (4) Any age: Salmonellosis, *C. perfringens*
 (5) After weaning: Helminths, *Eimeria, Yersinia*
 b. Acute death with or without bloat: *C. perfringens*
 2. Clinical signs: Diarrhea, dehydration, depression, loss of suckle reflex (metabolic acidosis), recumbency, anorexia, abdominal distention, focal, sometimes numerous and mobile bilateral pings
 3. Diagnosis: Submission of feces from representative number of cases or representative segment of bowel (tied off) from postmortem examination, for virology, bacteriology, and parasitology. Identification of *E. coli* strains as enterotoxigenic (ETEC), enteropathogenic (EPEC), enteroinvasive (EIEC), and enteroaggregative (EAggEC) is imperative, as is speciation of salmonellae and sensitivity profile of both, because of potential antibiotic resistance and zoonotic risk.
 4. Treatment
 a. Oral or IV electrolyte solutions
 (1) Oral: Mild to moderate dehydration, presence of suckle reflex, commercial products are useful. Continuation of milk feeding is important in meeting calves' caloric requirements but separate from electrolytes
 (2) IV: Moderate to severe dehydration, septic or toxic calves. Lactated Ringer's solution, 1.3% $NaHCO_3$. Spike fluids with dextrose because hypoglycemia is common. Catheters can easily be placed and maintained in the field

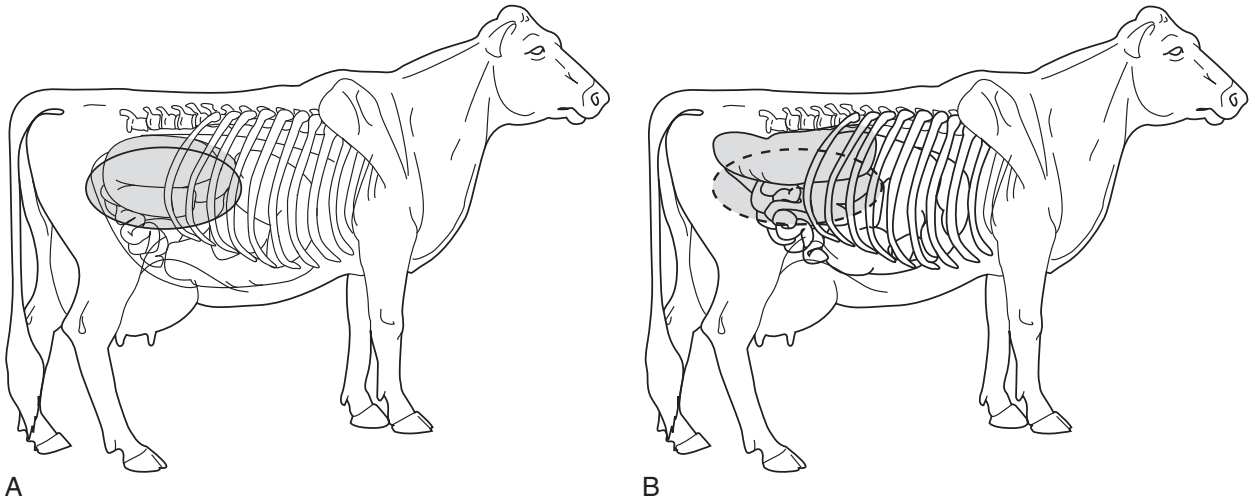


Figure 49-5 **A,** Cecal volvulus (right side). Area of tympanic resonance (shaded) heard in cows with a cecal volvulus. **B,** Cecal dilatation (right side). Area of tympanic resonance (shaded) heard in cows with cecal dilatation. (From Fubini S, Ducharme N. *Farm Animal Surgery*. St Louis, 2004, Saunders.)

(a) mmol HCO_3 = body weight (BW, kg) × base deficit (5 mmol/L mild, 20 mmol/L severe) × 0.5
(b) 1.3% $NaHCO_3$ = 155 mmol/L HCO_3

b. Antibiotics
(1) Use is controversial
(2) Definitely when septic
(3) Blood in feces: Probably, since likelihood of sepsis is increased
(4) Broad-spectrum and preferably bactericidal until sensitivity profile is known

5. Prevention: Isolation of cases; sanitation of calf barn, maternity pens, colostrums, and milk-feeding utensils; examine the time calves spend with dam, colostrum feeding, vaccination of cows prepartum to enhance passive transfer (*E. coli*, *C. perfringens,* rotavirus, and coronavirus), vaccination of calves before colostrum feeding (rotavirus, coronavirus)

G. Weaned calf scours
1. Parasites
a. Helminths (*Ostertagia ostertagi, Trichostrongylus* spp., *Cooperia* spp., *Nematodirus* spp.) controlled with pasture management and strategic anthelmintic administration
b. Coccidiosis (*Eimeria* spp.) controlled with cleaning of the environment and use of anticoccidials (e.g., lasalocid or monensin for prevention, amprolium or sulfadimethoxine for treatment)
2. BVDV controlled with identification and elimination of BVDV PI cattle and immunization

H. Necrotic enteritis
1. Etiology: *C. perfringens* type C
2. Pathophysiology: Necrotic β-toxin (major), α-toxin (minor). Trypsin inhibitors in colostrum lead to high incidence in very young calves. Small and large intestine affected
3. Clinical signs: Explosive yellow diarrhea, becoming brown and hemorrhagic. High mortality rate
4. Epidemiology: Not considered normal flora
5. Prevention: Isolation and sanitation; vaccination

I. Enterotoxemia
1. Generally a disease of young stock (i.e., less than 2 years old)
2. Etiology: *Clostridium perfringens* type D
3. Pathophysiology: Overnutrition leading to excessive growth of the bacteria; ϵ-toxin leading to peracute encephalomalacia, pulmonary and renal edema ("pulpy" kidney disease); acute hepatic glycogen release leading to hyperglycemia and glucosuria
4. Clinical signs: Sudden death
5. Prevention: Slow dietary adjustment; reduction in the starch concentration of the diet; vaccination

CARDIOVASCULAR SYSTEM DISEASE

I. Arrhythmia
A. Common auscultatable arrhythmias are atrial fibrillation and atrial and ventricular premature complexes
B. Not always associated with disease
C. Sinus arrhythmia present in only about 8% of healthy dairy cattle
D. Very common secondary to vagal nerve disease, GI disease, diseases causing changes in serum electrolytes and pH, and abdominal pain. Occasionally associated with myocardial disease. Ventricular premature contraction always associated with myocardial disease
E. Vagal nerve disease
1. Can be bradycardic
2. GI afferent or efferent fibers can cause arrhythmia
3. GI signs, such as bloat or abomasal displacement, often support diagnosis
F. Metabolic alkalosis is a risk factor (commonly because of abomasal disease)
G. Common myocardial disease in a dairy cow is infiltrative lymphosarcoma

II. Murmur
A. Most common murmur is from tricuspid (right atrioventricular) bacterial endocarditis. Variable grade, holosystolic or pansystolic
B. A complication of persistent bacteremia from mastitis or SC abscesses. *Arcanobacterium pyogenes*, *Streptococci* spp., *Staphylococci* spp., and *Pseudomonas* spp. are involved
C. Clinical signs include undulant fever, sepsis in other organs from showering of bacterial emboli from the valve, and sometimes heart failure

III. Ionophore toxicosis
A. Ionophores (e.g., monensin, lasalocid) are fed to cattle of many signalments to control and prevent coccidiosis, frothy bloat, rumen acidosis, and ketosis, and increase feed conversion efficiency
B. Ionophores are antimicrobial and select for those rumen fermenters that produce propionic acid. A side effect of feeding is depression of milk fat concentration
C. Cattle are less sensitive than horses
D. Toxicosis often occurs after a feed mixing accident
E. Clinical signs: Acute death or anorexia, diarrhea, ataxia, dyspnea, depression, and weakness. Chronic ill thrift if survive the acute phase
F. Pathology: Hydrothorax, ascites, pulmonary edema, cardiac and skeletal muscle hemorrhage, and necrosis
G. No specific treatment
H. Poor prognosis

IV. Cor pulmonale
A. Right ventricular heart failure due to pulmonary hypertension, usually a result of pneumonia
B. Signs are those of right-sided congestive heart failure, such as brisket edema and distended jugular veins

RESPIRATORY SYSTEM DISEASE

I. Sinusitis
A. Dehorning: Frontal sinusitis
B. Infected teeth: Maxillary sinusitis
C. Signs: Dehorning site may or may not be open, nasal discharge, upper respiratory tract stridor,

asymmetry in nostril air flow, foul-smelling breath, head pressing; chronic changes include swelling over facial bones, exophthalmus, and neurologic signs
D. Diagnosis: History, percussion over sinuses, radiographs, sinus-centesis
E. Treatment
1. Acute cases may respond to lavage at the dehorning site and parenteral broad-spectrum antibiotics
2. Chronic cases require sinus lavage, often with trephination
F. Control
1. Dehorn at a young age before cornual communication with the frontal sinus
2. Aseptic technique for dehorning procedures
3. Postsurgical care, including fly control and protection from inclement weather

II. Necrotic laryngitis (calf diphtheria)
A. Infection of the laryngeal mucosa
B. Seen primarily in calves, 3 to 18 months of age, housed in crowded, dirty conditions
C. Causes
1. Laryngeal contact ulcers followed by invasion of cartilage by *Fusobacterium necrophorum*
2. *Histophilus (Haemophilus) somnus* (primary agent): Perilaryngeal vasculitis with subsequent invasion by *F. necrophorum*
D. Signs: Anorexia, depression, fever, moist cough causing calf pain, foul-smelling breath, inspiratory dyspnea and loud stridor, open mouth breathing
E. Treatment: Antimicrobials and supportive therapy, tracheotomy in severe cases

III. Postcaval syndrome
A. Pathogenesis
1. Rumenitis and subsequent bacterial escape into portal circulation
2. Hepatic abscesses extend into hepatic veins or caudal vena cava leading to thrombosis
3. Thrombi break off and lodge in lungs
4. Necrosis through pulmonary veins and airways
B. Clinical signs: Anemia, wheezes, hemoptysis (mild to severe, sometimes acute and fatal)

IV. Acute bovine pulmonary emphysema and edema (fog fever)
A. Noninfectious, afebrile syndrome causing respiratory distress
B. Epidemiology
1. 4 to 10 days after introduction to lush pastures
2. Cattle more than 2 years of age
3. Morbidity can approach 100%; mortality can approach 50%
C. Pathogenesis
1. High concentrations of naturally occurring, L-tryptophan in lush fall pastures
2. Rumenal L-tryptophan → indoleacetic acid → 3-methyl indole (3MI, *Lactobacillus* spp.) → systemic circulation → lung → cytochrome P_{450} mixed function oxidases in Clara cells and type 1 pneumocytes metabolize 3MI to cytotoxic intermediates → pulmonary damage
D. Signs: Sudden death (forced movement may cause death), tranquil behavior, varying degrees of respiratory distress, crackles and wheezes (pulmonary emphysema). Cough is absent
E. Treatment: Remove from inciting pasture with minimal stress
F. Prevention
1. Pregraze with less susceptible stock
2. Supplement with hay and concentrate
3. Limit grazing time
4. Prevent the conversion of L-tryptophan to 3MI (polyether antibiotics, monensin, lasalocid)

V. Parasitic bronchitis and pneumonia (lung worms)
A. *Dictyocaulus viviparous*
B. Life cycle: Adults (8 cm long) in the trachea and bronchi → eggs hatch in airways and are coughed up, swallowed, and passed in feces → 5 days to develop to an L3 → ingested → penetrate intestines → systemic circulation → lungs. Larvae can overwinter on pasture
C. Clinical signs (severity of signs relate to the worm burden): Gradual onset of coughing and tachypnea, fever, anorexia, weight loss, harsh lung sounds (interstitial pneumonia)
D. Diagnosis: Clinical signs, pathology, detection of larvae in fresh feces (Baerman funnel sedimentation technique: Obtain fecal samples from the rectum to prevent contamination with free-living soil nematodes)
E. Treatment: Anthelmintic and antibiotics (to treat secondary bacterial pneumonia)

VI. Bovine tuberculosis (TB)
A. Bovine TB is zoonotic disease primarily in cattle; caused by *Mycobacterium bovis*
1. Can also be found in other domestic and wild animals
2. Wildlife reservoirs are important sources of disease spread to domestic animals. Reservoirs that have been identified include white-tailed deer (United States), European badgers (United Kingdom), and brush tailed possums (New Zealand)
B. Transmission
1. Animal-to-animal transmission is primarily through direct or indirect contact with infectious excretions from infected animals (aerosols, sputum, draining abscesses, colostrums, or milk)
2. Animal-to-human transmission can occur through direct contact with infected animals. Drinking of unpasteurized milk or eating uncooked products from infected animals is also a common method of zoonotic transmission
C. Clinical signs
1. In most cattle, signs of disease are inapparent
2. Bovine TB is a slowly progressive disease, and clinical signs are dependent on the extent of lesions and the organ systems involved
3. Often signs are limited to unthriftiness
4. With peripheral lymph node involvement, enlarged lymph nodes may be seen, and on occasion they may open and drain externally
5. With pulmonary involvement, signs include chronic nonproductive cough, increasing dyspnea, exercise intolerance, weight loss

D. Diagnosis
 1. Caudal fold tuberculin test
 2. Comparative cervical test
 3. Single cervical test
 4. γ-Interferon
 5. Necropsy (lesions: Granulomas in lymph nodes, lungs, GI tract, acid-fast–staining organisms in associated lesions), culture, PCR

E. Control
 1. Although tuberculocidal drugs have been used to treat cattle and other domestic animals, the cost, public health concerns, and regulatory issues severely limit treatment options
 2. Because bovine TB is considered a herd disease, infected herds are most commonly depopulated
 3. Protracted (2 to 5 years) test and removal schemes have also been used successfully to clear a herd of the disease. These schemes are typically conducted while herds are under quarantine, which can be a significant economic hardship
 4. Effective disinfectants will clearly say "tuberculocidal" on the label. Examples include phenols and 10% sodium hypochlorite

VII. Atypical interstitial pneumonia-acute respiratory distress syndrome of cattle
 A. Usually occurs later in the feeding period of fed cattle
 B. Typically in well-doing cattle
 C. Characterized by acute onset of dyspnea with no evidence of infectious disease (e.g., purulent nasal discharge, fever)
 D. Pathophysiology is unclear but likely a hypersensitivity reaction (parasites, dust, feed, BRSV)
 E. Gross pathology: Wet, heavy lungs with interstitial edema, especially in the caudodorsal lobes
 F. Treatment: Corticosteroids, salvage

VIII. Anaphylaxis
 A. The lung is the major target organ for type 1 hypersensitivity in cattle
 B. Vaccines, drugs, *Hypoderma* spp., insect bites and stings, blood transfusions, milk allergy
 C. Clinical signs: Rapid onset of acute dyspnea, with open-mouth breathing, frothing around the mouth, hyperpnea, pharyngeal and laryngeal swelling; urticaria (milk allergy)
 D. Treatment: Epinephrine, corticosteroids, NSAIDs

IX. BRD complex (shipping fever pneumonia)
 A. Multifactorial disease involving viral and bacterial pathogens, environmental factors, and host factors. The combination of stress and a viral infection can result in secondary bacterial pneumonia (viral-bacterial synergism)
 B. Typically seen in feeder calves 1 to 3 weeks after assembly in a feedlot or after introduction of new animals
 C. Environmental factors: Stress, weaning, transport, exhaustion, starvation, dehydration, chilling, overheating, commingling (social adjustment, crowding), processing (vaccination, worming), surgical procedures (dehorning, castration, spaying), rapid change to high-energy ration, dust

D. Viral agents associated with BRD
 1. Bovine herpes virus 1 (BHV-1, infectious bovine rhinotracheitis virus)
 a. Epidemiology: High attack rates, severe disease, and high case fatality rates in feedlot cattle. Reservoir is adult cattle because of latency in neural tissue, then viral shedding following stress
 b. Signs: Fever, anorexia, cough, dyspnea (mouth breathing) if trachea or larynx becomes obstructed with mucopurulent material, hyperemia of the muzzle, pustules or plaques on nasal mucosa, conjunctivitis. Severity of signs is dependent on the amount of stress and the occurrence of secondary bacterial pneumonia
 c. Necropsy: Congestion and hemorrhage of tracheal mucosa, pustules or plaques on respiratory and conjunctival mucosa
 2. Bovine viral diarrhea virus (BVDV)
 a. Immunosuppressive
 b. Synergism between BVDV and *Mannheimia (Pasteurella) haemolytica*
 3. Bovine respiratory syncytial virus (BRSV)
 a. Named for its characteristic (syncytial cell) cytopathology
 b. Epidemiology
 (1) High antibody prevalence in the cattle population
 (2) Lower respiratory tract pathogen
 (3) Morbidity can be high, with case fatalities up to 20%
 c. Clinical Signs
 (1) Respiratory signs predominate
 (2) Pyrexia, depression, and anorexia
 (3) Latter stages: Open-mouth breathing
 (4) SC emphysema
 d. Necropsy: Failure of lungs to collapse, diffuse interstitial pneumonia, subpleural and interstitial emphysema, edema, emphysematous bullae, syncytial cell formation
 4. Parainfluenza-3 (PI-3)
 a. Infections are widespread in the cattle population
 b. Mild infections, repeat infections, and subclinical infections are common
 c. Clinical signs: Fever, cough, nasal and ocular discharge, increased respiratory rate
 5. Other viruses of lesser clinical significance include bovine adenovirus, bovine rhinovirus, bovine reovirus, bovine enterovirus, bovine respiratory coronavirus

E. Bacterial pathogens associated with BRD
 1. *Mannheimia (Pasteurella) haemolytica*
 a. Biotype A and T
 b. Serotypes: 16 total; serotypes 1 and 2 are most common
 c. In normal, healthy, unstressed cattle A2 predominates in the nasal cavity, A1 is probably there, but in low numbers
 d. With stress, viral infection, and movement toward the feedlot, there is a shift to A1

e. By the time clinical cases of respiratory disease are observed, A1 has become predominant in the upper respiratory tract
f. Leukotoxin is important virulence factor

2. *Pasteurella multocida*
a. Tends to be more often associated with enzootic pneumonia of calves
b. Does not produce the leukotoxin
c. Prolonged or severe immunocompromise of respiratory tract is needed to infect lung with *P. multocida*

3. *Histophilus (Haemophilus) somnus*
a. Can cause primary pneumonia but often presents as a pleuritis
b. Associated with other clinical syndromes (thromboembolic meningoencephalitis, laryngitis, myocarditis, pericarditis, and arthritis)

4. *Mycoplasma* spp.
a. *Mycoplasma bovis* most common. Others include *Mycoplasma dispar* and *Mycoplasma bovirhinis*. Clinical signs include acute bronchopneumonia with fever; signs less severe than *Mannheimia haemolytica*
b. Pathology: Coalescing microabscesses
c. Recent association shown with BVDV
d. Also causes polyarthritis (feedlot) and otitis media (dairy)

F. Diagnosis of BRD
1. History
2. Physical examination
3. Necropsy
a. Specimens: Nasopharyngeal swabs, ocular swabs, tracheal swabs, transtracheal aspirates, bronchoalveolar lavage, and respiratory tract tissues obtained at postmortem (tracheal mucosa, bronchial lymph node, and lung)
4. It is important to remember that *M. haemolytica*, *P. multocida, M. bovis,* and *H. somnus* are normal inhabitants of the upper respiratory tract

G. Treatment of BRD
1. General principles: Treat early, treat long enough, treat with appropriate antimicrobial(s)
2. Antibiotics
a. Prevent or limit bacterial pneumonia
b. Directed toward *M. haemolytica, P. multocida, H. somnus, Mycoplasma* spp.
3. Corticosteroids
4. NSAIDs
5. Antihistamines
6. Supportive: Fluid therapy, B-complex vitamins, vitamin E, and selenium

H. Control and prevention of BRD
1. Address all underlying management problems
2. Eliminate the predisposing causes
3. Preconditioning program
a. Preconditioning: Reduce the morbidity by 23% and mortality by 50%
b. Example program is weaning, bunk feeding, castration, dehorning, worming, and vaccination 3 weeks before shipment
4. Metaphylaxis: Mass treatment with long-acting antimicrobial to reduce population of proliferating *M. haemolytica*, thereby reducing risk of pneumonia
5. Vaccination: IBR, BVDV, BRSV, PI-3, *M. haemolytica* (leukotoxin component), *P.* multocida, *H.* somnus, *M.* bovis

HEMATOLOGIC SYSTEM DISEASE

I. Degenerative left shift
A. Clinical pathological term that describes higher immature neutrophil numbers in blood than mature and with neutropenia
B. Common in bacterial diseases (mastitis, Salmonellosis, pneumonia, and peritonitis)

II. Bovine leukemia virus
A. Retrovirus; causes adult bovine lymphosarcoma. Infection is lifelong
B. Predilection for lymphocytes
C. Transmitted through blood or secretions containing lymphocytes (e.g., colostrum, nasal exudates, semen). Some vertical transmission
D. Prevention of new infections
1. Single use of hypodermic needles, rectal sleeves, and syringes
2. Feeding of colostrum from noninfected cattle or pasteurization of colostrums
3. Sterilization of medical and surgical equipment between cattle
4. Biting insect control
E. Most infections are asymptomatic. In surveys of infected cattle, it is common to find about 30% with asymptomatic lymphocytosis and about 5% with neoplasia
F. Diagnosis: Serum antibody agar gel immunodiffusion test or ELISA. Both highly specific and sensitive
G. Common sites (and signs) of neoplasia
1. Uterus (palpable masses)
2. Right atrium of heart (arrhythmia, heart failure)
3. Abomasum (melena)
4. Spinal canal (bilateral hindlimb extensor deficits)
5. Multiple lymph node involvement (bilateral iliac, supramammary, prefemoral, prescapular, and retrobulbar lymphadenopathy; secondary exophthalmos)
H. Treatment: None available. Neoplasia results in condemnation at slaughter
I. Eradication: Testing and removal from herd; management practices to prevent transmission

III. Sporadic (noninfectious) lymphosarcomas
A. Juvenile
B. Thymic
C. Cutaneous

IV. Anaplasmosis
A. Cause: *Anaplasma marginale*, transmitted by ixoides ticks in endemic (southern United States) areas. Reportable disease in many northern states
B. Pathophysiology: Chronic extravascular hemolysis leading to anemia
C. Clinical signs: Weakness, pale mucous membranes, and ill thrift from anemia (severe after

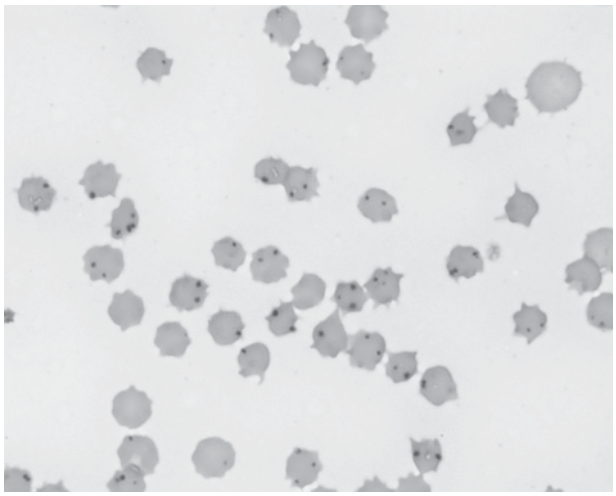


Figure 49-6 Wright's stain of blood from a heifer with *Anaplasma marginale*. The organism can be seen at the margin of several erythrocytes. (From Divers TJ. *Rebhun's Diseases of Dairy Cattle*, 2nd ed. St Louis, 2007, Saunders.)

chronic infection). Fever and jaundice in older, naïve cattle
- D. Diagnosis: Peripheral blood smear (Figure 49-6)
- E. Treatment: Oxytetracycline, blood transfusion in severe cases

V. Babesiosis
- A. Cause: *Babesia bovis* and *Babesia bigemina*, transmitted by ticks (genus *Boophilus*) in endemic (foreign to United States) areas
- B. Pathophysiology: Acute intravascular hemolysis, often fatal. Cerebral anoxia. Calves and *Bos indicus* cattle have innate immunity
- C. Clinical signs: Fever, jaundice or chocolate-colored mucous membranes, hemoglobinuria, hemoglobinemia. Hyperexcitability, convulsions
- D. Diagnosis: Peripheral blood smear
- E. Differential diagnoses: Bacillary hemoglobinuria (primarily small ruminants), copper toxicity, hepatotoxic plant ingestion
- F. Treatment: Several, including imidocarb

HEPATOBILIARY DISEASE

I. Ketosis and hepatic lipidosis
- A. Overview
 1. Common diseases of dairy cows
 2. Ketosis is described as primary or secondary, fresh cow or peak milk
 3. Proportion of liver as fat is a dynamic quantity, begins to increase prepartum; only causes signs of liver failure in excess of approximately 25% (wet weight)
 4. Ketosis: Excellent prognosis; hepatic lipidosis; guarded to grave prognosis
- B. Pathophysiology
 1. Negative energy balance
 a. Excellent production (e.g., peak milk ketosis)
 b. Impaired intake (e.g., secondary to left abomasal displacement and other fresh cow diseases)
 c. Exacerbated by heavy body condition (e.g., visceral compression from abdominal adipose depots)
 2. Fat accumulation in hepatocytes
 a. Inherently inefficient very low-density lipoprotein export capacity in bovine
 b. Flood effect after lipolytic stimuli in obese cows
 c. Leads to impaired gluconeogenesis
 d. End stage, blood ammoniation → hepatic encephalopathy
 3. Obesity: Risk factors
 a. Infertility in previous lactation resulting in extremely long previous lactation, with much of it in positive energy balance (poor production)
- C. Clinical signs
 1. Ketosis: Ketonuria, weakness (hypoglycemia), occasionally neurologic signs (manic licking, bellowing. i.e., nervous ketosis)
 2. Hepatic lipidosis: Large loss of body condition and chronic (i.e., longer than 5 days) duration of ketosis that is unresponsive to treatments. Appetite and mentation become depressed
- D. Diagnosis: Ketosis, ketonuria. Hepatic lipidosis, blind or ultrasound-guided percutaneous liver biopsy; flotation in varying concentrations of copper sulfate solution will quantify proportion of liver as fat
- E. Treatment
 1. Not all cases of ketosis require treatment (e.g., peak milk)
 2. Gluconeogenic substrates
 a. Oral propylene glycol
 b. Dextrose IV bolus (ketosis) or continuous infusion (hepatic lipidosis). Rate of infusion is titrated to prevent ketonuria and glucosuria
 c. Endogenous insulin response thought to have extended benefit (e.g., inhibited lipolysis)
 3. Corticosteroids (dexamethasone, isoflupredone acetate) enhance gluconeogenesis
 4. Forced feeding (e.g., orogastric intubation with feed slurries)
 5. Rumen transfaunation (beneficial if ketosis is secondary to rumen indigestion or propylene glycol use in chronic and rumen has soured)

II. Pregnancy toxemia
- A. Rare syndrome in cattle associated with impending parturition, ketosis, pregnancy with multiples, and malnutrition
- B. Clinical signs: Severe ketonuria, weakness, recumbency
- C. Treatment: IV dextrose, oral propylene glycol, parenteral corticosteroids. Induction of parturition if within 14 days of due date ($PGF_{2\alpha}$, dexamethasone). Improvement in plane of energy nutrition

III. Liver fluke
- A. *Fasciola hepatica*: Most common, found in southern and Pacific Northwest United States
- B. *Fascioloides magna*: Deer fluke found in northern sites

C. Life cycle includes intermediate snail host
D. Migration and cyst formation lead to liver damage, reduced performance, and secondary bacterial infection
E. Treatment and control: Flukecides, snail control, and limit exposure to snail habitats e.g., wet lands

IV. Liver abscesses
A. Most commonly seen in feedlot cattle on high-energy diets, secondary to rumenitis
B. Most common cause is *Fusobacterium necrophorum*
C. Most cases are subclinical and are diagnosed at slaughter, resulting in economic loss due to condemnation of the liver
D. Clinical disease is uncommon and signs are nonspecific
E. Sequelae include vena caval syndrome and peritonitis
F. Control: Gradual increase in proportion of diet as concentrate to reduce risk of rumenitis; feed-grade antimicrobials

INTEGUMENTARY SYSTEM DISEASE

I. Udder cleft dermatitis
A. Mixed cause: Gram-negative anaerobes, mange (sarcoptic, chorioptic)
B. Pathophysiology unknown: Probably initiated by local maceration
C. Usually self-limiting and mild, occasionally extensive and chronic, leading to secondary disease such as phlebitis

II. Subcutaneous abscesses
A. Numerous etiologies: Hypodermal injections, skin trauma, transdermal or hematogenous infection of hematoma
B. Common sites are over tuber ischii, gluteal muscles, semimembranosus and semitendinosus muscles, wings of atlas
C. Mixed bacterial growth common, including *Fusobacterium necrophorum*, *Arcanobacter pyogenes*, *E. coli*, and *Streptococcus fecalis*
D. Treatment includes surgical drainage and lavage. Most successful when abscess occupies SC space, where it may move to late in the disease, from deeper tissue planes. Broad-spectrum antibiotics indicated when associated with cellulitis but not for encapsulated abscesses

III. Dermatophilosis (rain scald)
A. *Dermatophilus congolensis*
B. Epidemiology: Contagious. Zoospores released after rain. Normal skin is resistant, macerated or traumatized skin is not
C. Clinical signs: Thick crusting of the skin, which peels easily to reveal a pink moistened surface, both skin and crust having a paintbrush appearance, the crust appearing concave with hair roots protruding. Dorsum and extremities affected
D. Diagnosis: Gram stain of impression smear. Longitudinally and transversely dividing gram-positive coccoid zoospores, forming parallel rows
E. Treatment: Removal and disposal of crusts; skin washing with iodine scrub; parenteral procaine penicillin G

IV. Bovine cutaneous papilloma (warts)
A. Infectious disease caused by bovine papilloma virus
B. Spread by direct or indirect contact with infected animal. Often spread from infected animal to naïve through use of common equipment such as tattoo pliers, grooming equipment, and dehorners
C. Usually self-limiting and self-curing
D. Warts can be surgically removed if indicated

V. Bovine dermatophytosis (ringworm)
A. *Trichophyton verrucosum* (zoonotic)
B. Spread by direct or indirect contact with infected animal
C. Most commonly seen in young animals in close confinement
D. Treatment may not be required since disease is often self-limiting. Includes exposure to sunlight and topical antifungals

VI. Lice infestation
A. Blood sucking and biting louse
B. Seen most commonly in winter months
C. Economic losses due to decreased performance
D. Clinical signs: Pruritus, alopecia
E. Treat with topical endectocide

VII. Hypoderma (warbles)
A. Larvae of the *Hypoderma* spp. fly
B. Life cycle
1. Adult fly deposits eggs on hair
2. Hatched larvae penetrate skin and begin migration
a. Esophageal submucosa (*H. lineatum*)
b. Tissues around spinal column (*H. bovis*)
c. Finish migration in the subdermal tissue of the back, where they become encysted and undergo molts to third stage larvae
3. L3 emerge from breathing hole in skin
4. Complete cycle takes 4 to 6 months
C. Most losses occur from damage to skin. Sometimes the inflammatory reaction to dead larvae in esophagus and spinal column will cause other signs such as paralysis
D. Control with fly abatement and strategic endectocide applications on cattle aimed at eliminating larvae prior to migration (avoid October 1 to March 1 window in northern United States)

VIII. Bovine herpes mammilitis (bovine herpes virus 2)
A. Contagious disease affecting the teat skin, causing much pain and interference with milking and teat function, predisposing to mastitis
B. Clinical signs: Swollen, edematous teats forming vesicles or ulcers. Convalescence is 3 to 10 weeks
C. Innate immunity is important. Seen more commonly in nulliparous heifers when endemic. Skin stressors such as extreme cold or mammary physiological edema can precipitate active disease
D. Treatment is purely supportive. Prevention is by isolation of cases, milking cows with condition last, and managing occurrence of skin stressors

NEUROLOGIC SYSTEM DISEASE

I. Listeriosis
A. *Listeria monocytogenes*

B. Epidemiology: Source of infection is usually ensiled feedstuffs with a section of feed that has undergone aerobic fermentation and spoilage
C. Pathophysiology: Entry through buccal mucosal abrasions or following loss of teeth and infection of nerve endings of trigeminal nerve, then infection in brainstem
D. Clinical signs: Vestibular nucleus; ataxia, circling, and head tilt to affected side. Trigeminal nucleus (sensory) and facial nucleus; ipsilateral facial hypalgesia and paralysis. Also causes abortion
E. Pathology: Microabscesses
F. Treatment: Parenteral procaine penicillin G
G. Prognosis: Poor

II. Nervous ketosis
A. Uncommon manifestation of ketosis in dairy cows associated with temporary manic behavior such as licking and bellowing
B. Pathophysiology is thought to be associated with production of isopropyl alcohol in the rumen from acetoacetic acid
C. Treat with ketosis therapies

III. Juvenile head tilt
A. Common secondary to otitis media-interna, after respiratory disease
B. Cause is usually mixed laryngeal and pharyngeal normal flora. *Mycoplasma* spp. implicated in pandemics
C. Pathophysiology
1. Ascending middle ear infection, progressing to inner ear, with tympanic bullae osteitis
2. Vestibulocochlear neuritis → ipsilateral head tilt
3. Facial nerve infection can develop because of proximity to tympanic cavity (ptosis, drooped ear, flaccid lip and nostril)
D. Treatment: Myringotomy, extended antibiotic therapy (broad spectrum, including *Mycoplasma* spp.)
E. Poor prognosis for full recovery

IV. Ammoniated feed toxicosis
A. Application of anhydrous ammonia to forage improves the nutritional density and reduces fungal metabolites, but at more than 3% forage dry matter weight, it may result in the formation of 4-methylimidazole, and toxicosis
B. Urea is added to diets as a source of non-protein nitrogen and may cause ammonia toxicity if overfed. This disease also presents with neurological signs (i.e depression); ammonia kills quickly and so cattle are often found dead. This disease has a different pathogenesis (i.e. hyperammonemia) compared to ammoniated feed toxicosis
C. Clinical signs: Hyperesthesia, ataxia, mania, convulsions
D. Diagnosis: Serum and cerebrospinal fluid ammonia assay
E. No specific treatments have been identified

V. Lead toxicosis
A. Exposed by licking or chewing lead-containing materials or drinking contaminated petroleum distillates
B. Pathophysiology: Inhibition of α-aminolevulinic acid dehydrase; cerebral necrosis, swelling, neurotransmitter dysfunction, decreased glucose uptake
C. Clinical signs: Blindness, ataxia, and depression
D. Diagnosis: Whole blood and bone (chronic, low exposure) assay. Free erythrocyte porphyrins and α-aminolevulinic acid, cerebral histopathology
E. Treatment: Calcium disodium ethylenediaminetetraacetic acid (EDTA), thiamine

VI. Infectious thromboembolic meningoencephalitis (TEM, ITEM)
A. Caused by *Histophilus somnus*
B. Pathophysiology: Multifocal septic embolism in the central nervous system, leading to vasculitis, encephalitis
C. Clinical signs: Depression, dementia, recumbency, weakness, ataxia, blindness, opisthotonus, nystagmus
D. Treatment and control: Long-acting antimicrobials; immunization with *H. somnus* bacterin. Prognosis is poor
E. *H. somnus* is also associated with pneumonia, pleuritis, laryngitis, arthritis, myocarditis, and pericarditis

VII. Polioencephalomalacia
A. Cause is unclear, but thiamine inadequacy is suspected
1. Thiamine-deficient diet
2. Decreased thiamine microbial synthesis in rumen
3. Thiaminases in the rumen
4. Thiamine inhibitors increased thiamine demand
5. Sulfide toxicity
B. Clinical signs: Acute onset of blindness, head pressing, easily irritated, occasional convulsions, recumbency, opisthotonus, and nystagmus
C. Treatment and control: Thiamine hydrochloride, parenteral for treatment, dietary supplementation for prevention and control

VIII. Nervous coccidiosis
A. Seen most commonly in newly weaned calves often when first moved in feedlot or background operation
B. Coincides with enteric coccidiosis
C. Clinical signs: Muscle twitching, incoordination, intermittent to continuous seizures
D. Treatment and control: Amprolium, sulfonamides. Control by maintaining clean environment and the feeding of anticoccidials (e.g., lasalocid, monensin)

IX. Bovine spongiform encephalopathy (BSE, mad cow disease)
A. Cause
1. BSE is one of several diseases categorized as transmissible spongiform encephalopathies
2. BSE is a fatal disease with no treatment
3. The common name, “mad cow disease,” is related to abnormal motor nerve control coupled with aggressiveness
4. The disease is believed to be caused by a self-replicating protein (a prion; PrP^{Sc}) rather than a bacterium or virus. This abnormal protein causes normal prion proteins, found in the brain of cattle, to change conformation to PrP^{Sc}
5. Excessive accumulation of PrP^{Sc} results in cell death

B. Transmission: The disease is believed to occur following the ingestion of PrP^{Sc} proteins in ruminant derived protein contaminated diets
C. Clinical signs: Changes in temperament, such as nervousness or aggression, abnormal posture, incoordination, and difficulty in standing, abnormally stilted gait, high stepping, heightened sensory perception, itching, excessive licking
D. Control: BSE is controlled by not feeding ruminant-derived proteins back to ruminants, a practice that has been banned in the United States
E. BSE is zoonotic. Human infection results from the ingestion of infected bovine nervous system tissue. This is prevented by excluding cows with neuroligcal disease and recumbent cows from slaughter, excluding all nervous tissue from the food chain, and adapting harvest techniques to prevent carcass contamination with nervous tissue.

X. Rabies
A. Caused by *Lyssavirus*
B. Cattle exposed usually from the bite of rabid wildlife
C. Should be listed as a differential diagnosis for any unexplained acute neurologic disease, because of the zoonotic threat
D. Clinical signs
1. Clinical course of 1 to 10 days with rapid progression of signs and eventual death
2. Early signs are nonspecific and include anorexia, depression, or other behavioral changes such as restlessness
3. Two forms have been described (may alternate in same animal):
a. Furious rabies: Hyperexcitable, hyperesthetic, fearful, enraged, bellowing
b. Dumb rabies (most common in cattle): Severe depression; paresis or paralysis; flaccid facial muscles, tongue, tail, anus; blindness, strabismus, nystagmus
4. Hypersalivation
E. Diagnosis: History of exposure to suspected bite of wild animal, clinical signs, postmortem examination of brain (negri bodies on histopathology, fluorescent antibody detection of antigen)
F. Prevention: Vaccination and control of wildlife reservoirs

XI. Pseudorabies (Aujesky disease)
A. Caused by a herpes virus that naturally infects and can be carried by swine
B. Cattle are susceptible to infection and the disease is typically fatal
C. Clinical signs
1. Acute and severe pruritis with self-mutilation, bellowing, hypersalivation, and chewing of the tongue
2. As disease progresses, other neurologic signs may be present, including hyperesthesia, tenesmus, excessive licking and mastication, and vocalization, with eventual coma and death
D. There is no treatment and the disease is usually fatal
E. Prevention: Pseudorabies has been eradicated from most domestic hogs but is still found in feral hogs. Prevention is based on eliminating contact between swine and cattle

XII. Botulism
A. Botulism is caused by botulinum toxin, a neurotoxin produced by *Clostridium botulinum* (anaerobic, gram-positive, spore-forming rod)
B. Botulism occurs when animals ingest preformed toxins in food or *C. botulinum* spores germinate in anaerobic tissues and produce the toxin. Common cattle exposure occurs with decaying vegetable matter (grass, hay, grain, spoiled silage) and carcasses (e.g., small mammals) unintentionally incorporated into feedstuffs such as hay during harvest
C. Clinical signs
1. Botulism is characterized by progressive motor paralysis
2. Clinical signs include axial skeletal muscle paralysis, difficulty chewing and swallowing, blindness, and generalized weakness
3. Death usually results from paralysis of respiratory or cardiac muscles
D. Diagnosis
1. Often based on clinical signs and exclusion of other diseases
2. A definitive diagnosis can be made if botulinum toxin is identified in feed, stomach or intestinal contents, or feces
E. Control and prevention
1. Treatment usually supportive
2. Botulinum antitoxin is sometimes used in animals
3. Vaccines can be used in endemic areas
4. Proper harvesting and storage of feedstuffs to reduce the risk of spoilage
5. Feedstuffs containing carcasses should not be fed

XIII. Tetanus
A. Caused by neurotoxin produced by the bacterium *Clostridium tetani.* Spore-forming bacteria; can persist in the environment for years. Spores found in feces and soil
B. Cattle exposure is typically via a wound (e.g, castration, tail docking, puncture)
C. Cattle are less susceptible than are other species, including horses and sheep
D. Clinical signs: Initially, stiffness, muscle tremors and prolapse of the third eyelid. Hyperesthesia, tetany, convulsions, and death
E. Diagnosis is usually based on history and clinical signs
F. Treatment and control
1. Treatment is usually unrewarding. Includes antibiotics, tetanus antitoxin, supportive care
2. Control
a. Vaccination
b. Good surgical technique, postsurgical and instrument care
c. Prophylactic use of tetanus antitoxin and/or toxoid prior to surgical procedures

XIV. Peripheral nerve disease
A. All are treated supportively (NSAIDs, corticosteroids), vary in severity (paresis to paralysis), and vary in prognosis (often predictable based on severity of signs and changes in signs over several days)

B. Radial nerve
 1. Most frequently affected by trauma incurred from restraint on foot-trimming table
 2. Clinical signs are unilateral distal limb extensor deficits while non–weight bearing, with toe drag, elbow drop, and dorsal digit analgesia
C. Sciatic nerve
 1. Most frequently affected by calving trauma, in nulliparous cows, often with simultaneous lumbar spinal nerve or obturator nn. trauma (adductor mm. deficits), and by gluteal mm. injections in calves
 2. Clinical signs: Slight lowering or dropping of hip and hock with fetlock knuckling, toe drag, weight bearing on dorsum (severe) or sole. Often recumbent if severe and bilateral. Analgesia distal to stifle, except medially
D. Tibial nerve
 1. Most frequently affected by distal, caudal thigh intramuscular injection, or from compartmental syndrome in downer cows
 2. Clinical signs: Fetlock knuckling, dropping of the hock. Toe does not drag. Weight bearing only on sole. Plantar metatarsal and digit analgesia
E. Peroneal nerve
 1. Most frequently affected by compartmental syndrome in downer cows
 2. Clinical signs: Straightening of the hock, fetlock knuckling, weight bearing sometimes on dorsum. Dorsal metatarsal and fetlock analgesia. Signs can be difficult to distinguish from sciatic n. and tibial nerve paralysis

OPHTHALMIC DISEASE

I. Ocular squamous cell carcinoma (cancer eye)
 A. Most common tumor diagnosed in cattle
 B. Seen most commonly in cattle with light-pigmented eyelids and with constant exposure to ultraviolet (UV) light
 C. Clinical signs
 1. Include corneal or eyelid, small, white plaques or large wart-like masses
 2. Secondary signs include blepharospasm, epiphora, and photophobia
 3. Metastasize to regional lymph nodes
 D. Treatment: If localized, surgical resection and/or cryotherapy. No practical treatment if metastatic and condemned at slaughter
II. Infectious bovine keratoconjunctivitis (pink eye)
 A. Most commonly caused by *Moraxella bovis*. Other infectious agents include *Mycoplasma* spp. and BHV-1
 B. Epidemiology
 1. Most commonly seen in summer and fall
 2. Spread by face flies
 3. Factors that cause ocular irritation increase risk (e.g., tall grass, irritating plants like thistles, UV light)
 4. Exacerbated in cattle with light pigment around eyes (e.g. Herefords, Holsteins)
 C. Clinical signs: Early signs include blepharospasm, epiphora, and photophobia. With progression, chemosis, corneal edema, corneal ulceration, and blindness
 D. Treatment: Systemic or local antimicrobials, local corticosteroids, protect cornea from further irritants (e.g., patch, tarsorrhaphy)
 E. Prevention includes vaccination (*Moraxella bovis*), face fly control, topical insecticides, insecticide impregnated ear tags, pasture management, weed control

URINARY SYSTEM DISEASE

I. Leptospirosis
 A. Cause: *Leptospirosis borgpetersenii serovar hardjo*. Cattle are reservoir host
 B. Pathophysiology
 1. Infection occurs by ingestion or across nasal or ocular mucosa
 2. Most commonly causes chronic nephritis
 C. Clinical signs
 1. No signs specific to the urinary tract but can lead to infertility or abortion
 2. Other strains can sometimes cause severe hemolysis, hepatitis, and nephritis
 D. Diagnosis: Immunofluorescent antibody staining of urinary sediment, preferably collected after diuresis, for identification of all Leptospira. Serum antibodies are useful in identifying serovar
 E. Treatment: Parenteral oxytetracycline
 F. Prevention: Bacterins. Efficacy differs by manufacturer
II. Urethral calculi
 A. Most commonly seen in feedlot cattle
 B. Magnesium ammonium phosphate (struvite) stones are the most common
 C. Clinical signs: Stranguria, dribbling urine, dry prepuce with crystals on preputial hairs, ventral abdominal edema (“water belly”), ventral abdominal distention, pelvic urethral spasm. If bladder ruptures, depression, anorexia, peritonitis, death
 D. Treatment: Salvage or perineal urethrostomy
 E. Prevention
 1. Urinary acidifier, such as ammonium chloride or ammonium sulfate at 1% to 2%, can be added to the diet
 2. Accessible, good-quality drinking water
 3. Dietary salt will increase water consumption and dilute the urine
III. Pyelonephritis
 A. Either caused by ascending vaginal flora (coliforms, fecal *Streptococci* spp., gram-negative anaerobes) or *Corynebacterium renale*, a contagious pathogen spread by fomite or by servicing bulls
 B. Vaginal trauma at calving is a common risk factor. Others include urinary bladder catheterization, or neurologic disease preventing bladder void
 C. Diagnosis: Urinalysis, serum chemistry, renal sonography, culture, and sensitivity
 D. Treatment: Antibiotics and IV fluid therapy
 E. Prognosis is poor unless diagnosed and treated in acute phase

OTHER DISEASES: ANTHRAX

I. Introduction
 A. Anthrax is a zoonotic disease that affects most mammals and several species of birds. It is a reportable disease
 B. Anthrax is caused by *Bacillus anthracis*, a spore-forming, gram-positive facultatively anaerobic rod
 C. Anthrax spores are extremely resistant to inactivation by heat or chemicals and can survive in the environment for decades
 D. In infected animals, large numbers of vegetative bacteria are present in hemorrhagic exudates from the mouth, nose, and anus. When they are exposed to oxygen, these bacteria form spores and contaminate the soil. Sporulation also occurs if a carcass is opened
 E. Human cases usually develop after exposure to infected animals and their tissues. The three forms are cutaneous, GI, and inhalational

II. Transmission: Cattle usually become infected when they ingest or inhale spores in soil or on plants in pastures. Outbreaks are often associated with heavy rainfall, flooding, or drought. Contaminated bone meal and other feed can also spread this disease

III. Clinical signs
 A. In cattle, peracute systemic disease is common; sudden death may be the only sign
 B. Staggering, trembling, and dyspnea may be seen in some animals, followed by rapid collapse, terminal convulsions, and death
 C. Bloody discharges from the nose, mouth, and anus are sometimes seen

IV. Pathology
 A. If anthrax is suspected, necropsies should be avoided to prevent contamination of the surrounding area with spores
 B. Rigor mortis is usually absent or incomplete
 C. Carcass is typically bloated and decomposes rapidly
 D. Dark, tarry blood may ooze from the body orifices

V. Control and prevention
 A. In the face of an outbreak, prophylactic antibiotics should be used. Vaccination recommended in endemic areas
 B. Restrict access to high risk grazing areas
 C. Carcasses should not be opened and should be buried

FOREIGN ANIMAL DISEASE

I. Reportable diseases
 A. Reportable diseases are diseases considered of great socioeconomic or public health importance. Local, state, and national agencies require that such diseases be reported when they are suspected or diagnosed by veterinarians or laboratories. Reporting allows for the collection of statistics that show how often the disease occurs, which in turn helps identify disease trends and track disease outbreaks
 B. In the United States, reportable diseases include Office International des Epizooties list A and B disease and diseases listed as foreign animal diseases by the U.S. Department of Agriculture. In addition, individual states may designate other diseases as reportable when they are of particular interest to that state's animal industries

II. Foot and mouth disease (FMD)
 A. Introduction
 1. FMD is a highly contagious viral disease of livestock
 2. Foot and mouth disease virus (FMDV) is in the family Picornaviridae. There are 7 immunologically distinct serotypes and 60 subtypes
 3. FMDV primarily affects cloven-hoofed domestic and wild animals, including cattle, pigs, sheep, goats, camelids, and water buffalo
 4. Cattle are generally the first species to manifest signs of FMD and so are considered "indicators" of this disease. Lesions in cattle are typically more severe and progress more rapidly compared with other species
 5. Endemic areas include parts of Asia, Africa, South America, and the Middle East. The last United States outbreak was in 1929
 B. Transmission
 1. Transmission occurs primarily by respiratory aerosols and direct or indirect contact with infected animals
 2. Animals may also become infected by ingesting animal products contaminated with the virus, such as meat, milk, bones, and cheese
 3. Fomites, such as boots, hands, clothing, vehicles, and equipment, can spread the virus from animal to animal or farm to farm
 4. Ruminants can carry the virus for long periods in their pharyngeal tissue. Recovered or vaccinated cattle exposed to diseased animals can be healthy carriers for as long as 24 months
 C. Clinical signs
 1. Clinical signs include depression, anorexia, hypersalivation, serous nasal discharge, decreased milk production, lameness, and reluctance to move
 2. Fever above 104° F is common
 3. Vesicles progress to erosions in the mouth, nares, muzzle, dental pad, coronary band, interdigital space, and teats
 4. Abortion; acute death in calves due to severe myocardial necrosis
 D. Diagnosis
 1. Clinical signs of fever, salivation, and lameness with vesicles or erosions in the mouth and coronary band-interdigital space
 2. Samples include vesicular fluid and epithelium covering vesicles
 3. PCR, ELISA, virus isolation
 E. Control
 1. A quick response is imperative in containing an outbreak. State and federal veterinarians should be notified immediately of any suspected vesicular disease
 2. Suspected animals and premises should be quarantined immediately
 3. Premises should be disinfected. Effective disinfectants include sodium hydroxide (2%),

sodium carbonate (4%), citric acid (0.2%), potassium peroxymonosulfate
4. Vaccination can be used during an outbreak to control spread or prophylactically. FMD vaccines must closely match the type and subtype of the prevalent FMDV strain. Currently, there is no universal vaccine against FMD

III. Rinderpest
A. Rinderpest is an acute, contagious disease of cattle, domestic buffalo, and some species of wildlife. It is characterized by high fever, oral erosions, diarrhea, lymphoid necrosis, and high mortality
B. Rinderpest virus is an RNA virus in the family Paramyxoviridae
1. One serotype, but individual strains vary in their virulence
2. Most cloven–hooved animals are susceptible
a. Cattle, buffalo, and yaks are most susceptible
b. Sheep, goats, pigs, and wild ungulates can also be affected
C. Most commonly seen in Africa and central Asia
D. Transmission: Shed in nasal and ocular secretions and feces, through direct or close indirect contact with infected animals
E. Clinical signs
1. Peracute, acute, or subacute forms, depending on the virulence of the strain and resistance of the infected animal
2. Peracute form is seen in highly susceptible and young animals. Signs include high fever, congested mucous membranes, and death within 2 to 3 days
3. Acute or classic form
a. Initial signs include depression, anorexia, high fever, and increased respiration and heart rate
b. Signs progress to include mucous membrane congestion, serous to mucopurulent nasal and ocular discharge, oral erosions, and hypersalivation
c. In later stages, animals develop severe watery or hemorrhagic diarrhea containing mucus and necrotic debris, tenesmus, dehydration, abdominal pain, weakness, and recumbency
d. Death may occur within 8 to 12 days
4. Subacute or mild form. May include any of the classic signs but less severe and lower morbidity
F. Diagnosis
1. Clinical picture involves oral lesions and GI disease
2. Diagnostic samples include blood in EDTA or heparin, swabs of lacrimal fluid, and necrotic tissue from oral lesions
G. Control
1. The affected area should be quarantined
2. Exposed or infected animals are slaughtered and the carcasses burned or buried
3. Effective disinfectants include phenols, cresol, 2% sodium hydroxide

IV. Vesicular stomatitis
A. Vesicular stomatitis virus (VSV) is a member of the genus *Vesiculovirus* in the family Rhabdoviridae
B. Cattle, swine, horses, donkeys, mules, South American camelids, and humans can be affected by VSV
C. In humans, vesicular stomatitis is an acute illness with a clinical course that resembles influenza
D. Transmission
1. By insect vectors, including sand flies, black flies, and mosquitoes
2. Once in a herd, VSV can spread by direct contact or by exposure to contaminated fomites
3. Humans can become infected when handling affected animals, contaminated fomites and tissues
E. Clinical signs
1. Fever and hypersalivation are the first signs typically recognized
2. Vesicles located in and around the mouth and foot. Horses: Vesicles on upper surface of tongue, the gums, the lips, and around the nostrils and corners of the mouth. The hooves may have secondary lesions
4. In cattle, the vesicles are found on the hard palate, lips, and gums and may extend to the nostrils and muzzle. The hooves may have secondary lesions
5. In pigs, vesicles usually appear first on the feet, and the first symptom may be lameness. The muzzle is also frequently affected in swine
F. Diagnosis: Vesicle fluid, the epithelium covering vesicles, epithelial flaps from freshly ruptured vesicles, or swabs of the ruptured vesicles are the preferred diagnostic samples
G. Control
1. During an outbreak, quarantines are placed on facilities with infected animals
2. Isolation of symptomatic animals helps control the spread of vesicular stomatitis within a herd
3. VSV is susceptible to 1% sodium hypochlorite, 70% ethanol, 2% glutaraldehyde, 2% sodium carbonate, 4% sodium hydroxide, 2% iodophore disinfectants, formaldehyde, and chlorine dioxide

Suggested Reading

Books
Smith BP ed. *Large Animal Internal Medicine*, 4th ed., Mosby.
Radistits OM, et al. eds. *Veterinary Medicine: A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats*, 10th ed., Saunders.
Anderson DE, Rings MR eds. *Current Therapy: Food Animal Practice*, 5th ed, Saunders.
Haskell SR ed. *Blackwell's Five-Minute Consultant: Ruminants*, 1st ed., Wiley-Blackwell.
Youngquist R, Threlfall W. *Current Therapy in Large Animal Theriogenology*, 2nd ed., Saunders.
Websites
Gray Book on Foreign Animal Diseases - Accessible at http://www.vet.uga.edu/vpp/gray_book2
Veterinary Clinics of North America: Food Animal Practice (Serial) - Accessible at http://vetfood.theclinics.com/current

Camelid Medicine and Management

50 CHAPTER

Margaret A. Masterson

GENERAL INFORMATION ABOUT CAMELIDS

South American camelids have become popular livestock in North America over the past couple decades. The South American camelids consist of four species: the llama, the alpaca, the vicuña, and the guanaco. The vicuña and guanaco are not as popular as the others in North America. The llama is the largest, weighing 325 to 550 lb on average. It has an undercoat with long guard hairs and banana-shaped ears. The alpaca is smaller, averaging 125 to 275 lb. It has two recognized breeds: the suri has fiber that lacks crimp and hangs in ringlets, and the huacya, which has fiber that sticks up from the skin and has crimp.

Llamas are important in South America as pack animals and as meat and fiber animals. Alpacas are the major fiber-producing animals in the Altiplano region. In North America both species are used as companion animals and for showing. Llamas are becoming important as guard animals for small ruminants and alpacas are working toward creating a commercial fiber industry in North America.

VITALS AND TERMS

I. Temperature: 99° to 101.5° F
II. Heart rate
 A. Adult: 60 to 80 beats/min
 B. Cria: 70 to 90 beats/min
III. Respiratory rate: 20 to 30 breaths/min
IV. C1 contractions (ruminations) 3 to 4/ min, weaker than in ruminants
V. Male or stud: Male camelid
VI. Female: Female camelid
VII. Maiden: Young female
VIII. Gelding: Castrated male camelid
IX. Cria: Baby camelid
X. Cush: Term used for sternal recumbency

PHYSICAL RESTRAINT

I. Many domestic camelids are halter trained. They can also be handled in a chute
II. Restraint can often be done by holding them around the neck and applying pressure over the withers to prevent jumping
III. Unruly camelids often respond to grasping the base of the ear as is often done in equine restraint
IV. Camelids can often be herded into a smaller pen by pulling a rope taut between two people and then using it as a movable fence. Most animals will not try to cross the rope
V. Often when a llama or alpaca feels stressed or threatened it will lie down in sternal recumbency, or cush. This position can then be maintained by applying pressure to the withers
VI. Irritated camelids can kick; however, because they lack a hoof, their kick is not as painful as that of a horse or cow
VII. Their most common defense mechanism it spitting, whereby they regurgitate ingesta and "spit" it at the offender. Although their spit has a very offensive odor it is not painful

NUTRITION

I. Body-condition scoring
 A. Scale: 1 to 5, with 1 being thin and 5 being overweight
 B. Very important because the dense fiber can hide the animals' true body condition
II. Crias should be weighed daily for the first 2 to 4 weeks of life. This is the only accurate way to be sure they are receiving adequate nutrition
 A. Llama crias should gain 1 lb/day
 B. Alpaca crias should gain at least 0.5 lb/day
III. Water
 A. The most important nutrient
 B. Camelids require about 1 to 2 gallons of water per 100 lb/day. This can vary greatly depending on weather and feed intake
IV. Protein requirements vary from 10% to 16% of the dry matter feed, based on growth, gestation, and lactation. Growth and lactation require higher protein levels
V. Energy
 A. Requirements are between 61 and 85 kcal metabolizable energy/kg body weight
 B. Camelids are considered better at utilizing poor quality forages than are traditional ruminants
 C. They will get a significant amount of their nutrition from quality pasture if it is available
 D. In general, adults require 66% to 70% of their diet as forage and 30% to 35% as grain or supplement
 E. Forages with 10% to 14% crude protein and total digestible nutrients at 55% to 62% are preferable
 1. Therefore, grass hays are better than legumes
 2. Alfalfa, clovers, and endophyte infected fescues should be avoided or fed at low levels

UNIQUE ANATOMY AND PHYSIOLOGY

I. Split upper lip
II. Figure 8 chewing pattern
III. Fighting teeth
 A. The canines and the single upper third incisor (six teeth total)
 B. These are sharp, pointy, curved fanglike teeth
 C. Erupt in males at 2 to 3 years of age and some older females
 D. Males will use these teeth to slice each other's ears, necks, and testicles
 E. These teeth are usually removed in males to prevent them injuring each other. They are removed by cutting the tooth level with the gum, often with obstetrical wire (OB wire)
IV. Three-compartment stomach
 A. Compartment 1 (C1) and compartment 2 (C2) are anaerobic fermentation compartments where microorganisms produce microbial protein and volatile fatty acids
 B. Compartment 3 (C3) is the true stomach
 C. Camelids do chew their cud and have four to seven forestomach contractions per minute
V. Feces is usually pelletted, and animals use a common dung pile
VI. The foot has two digits each with a pad and a toenail
VII. They have true valves in the jugular vein
VIII. Erythrocytes are small and oval. They have a high oxygen-carrying capacity and low viscosity, making them well suited to high altitudes
IX. Crias are dependent on passive immunity through colostrums

VACCINATION

I. Camelids in the United States are generally vaccinated for the following:
 A. *Clostridium perfringens* type C and D and tetanus
 B. Rabies (killed) in endemic areas
II. Other optional vaccines, depending on the area and disease situation, include the following:
 A. Eight-way clostridial vaccine
 B. Leptospirosis
 C. Equine herpesvirus type 1 (EHV-1)
 D. *Escherichia coli*

INTERNAL PARASITES

I. Meningeal worm: *Parelaphostrongylus tenus*
 A. White-tailed deer is the primary host; snails and slugs are the intermediary host
 B. In aberrant hosts such as camelids, the snail or slug is ingested and the larva is released in the stomach
 C. The larva migrates to the spinal cord or brain, where it produces neurologic signs, dependent on its location
 D. Common signs are ataxia, lameness, paralysis, recumbency, blindness, and abnormal head position. Secondary complications of being down are common such as pneumonia
 E. Death is possible
 F. Presumptive diagnosis is based on history, season of the year, and possible eosinophilia in the cerebrospinal fluid
 G. Once the animal is down, prognosis is guarded
 H. Treatment consists of multiple days of fenbendazole or ivermecterin or both
 I. Prevention includes frequent (i.e., every 4 to 6 weeks) dewormings with Ivomec or Dectomax, excluding deer from pastures and avoiding wet pastures where snails and slugs might be present
II. Coccidia
 A. Several species of eimeria have been identified in camelids, including *Eimeria lamae*
 B. Most infections (except *Eimeria macusaniensis*) are self-limiting and cause diarrhea and enteritis only in young animals
 C. Diagnosis is based on fecal flotation and identification of oocysts
 D. Treatment is with amprolium hydrochloride (Corid) or sulfa drugs
III. *Eimeria macusaniensis (E. macusaniensis, E. mac)*
 A. Coccidian of all ages of camelids
 B. Different from *E. lamae* and others in juveniles
 C. Often found in conjunction with other *Coccidia* spp.
 D. Can cause a spectrum of disease ranging from subclinical shedding to severe protein-losing enteropathy and death
 E. Signs include lethargy; decreased appetite; severe weight loss; severe watery diarrhea (37%), especially in young animals; "cobblestoning," or white plaques on intestines; hypoproteinemia, usually without anemia; hypoalbuminemia; and hyperglycemia
 F. 50% to 70% of all cases result in death, even with aggressive treatment
 G. *E. macusaniensis* has a long prepatent period, 32 to 40 days after first ingestion. Severe clinical disease may develop before fecal tests are positive for oocysts
 H. Treatment includes coccidiostats such as amprolium hydrochloride and sulfa drugs as well as plasma transfusion
 I. May want to institute treatment in any severely hypoproteinemic animal
IV. Nematodes
 A. *Haemonchus, Ostertagia, Trichostrongylus, Strongyloideia, Nematodirus, Camelostrongylus, Cooperia, Capillaria,* and *Trichurus* spp. have all been found in camelids
 B. Levels are often low as a result of the animal's use of the communal dung pile and owners frequently deworming for meningeal worm
 C. Parasitism can be a problem in poorly managed pastures or if animals are housed with sheep
 D. Treatment is best based on fecal egg counts (Stolls or McMasters) and deworming only when indicated rather than routinely as resistance to dewormers is beginning to become more prevalent in camelids
V. Cestodes: Tapeworms
 A. *Moniesia* spp. and *Thysaniezia* spp.

B. Often seen by owners but usually cause little problem to the animal except perhaps clumping of the feces
C. Treatment is with fenbendazole or praziquantel

VI. Trematodes: Liver flukes
A. *Fasciola hepatica* is found in the western and southern parts of the United States
B. Snails are the intermediate host
C. Signs can include acute hepatitis or chronic bilistasis with hepatic fibrosis, anemia, edema, and ill thrift
D. Diagnosis is based on fecal sedimentation technique
E. Treatment is with clorsulon or albendazole

INFECTIOUS DISEASE OF CAMELIDS

Camelids are susceptible to many of the same diseases as other domestic animals, including viral diseases like blue tongue, rabies, and rotavirus; bacterial diseases including *E. coli*, clostridial diseases, tuberculosis, and Johne disease, and many fungal infections.

The following is a list of infectious diseases that have unique presentation or importance in camelid medicine:

I. Bovine viral diarrhea (BVD)
A. Recognized as a disease problem in camelids since at least 2000
B. In cattle BVD can cause abortion at any age. Infection with non-cytopathic strain between 40 and 120 days' gestation results in a persistently infected calf (PI)
C. Crias infected in utero can become PIs
1. PIs do not mount an immune response to BVD and therefore shed virus their entire life
2. PIs are a major source of acute infection for other alpacas in the herd
D. Signs of acute BVD in camelids are oral ulcers, uncomfortable eating, off feed, death (due to hepatic lipidosis), abortion, stillbirth, and PI crias
E. No animals have been reported to have diarrhea

II. *Mycoplasma haemolamae*
A. Formally called *Eperythrozoon*
B. Red blood cell (RBC) parasite
C. Surveys suggest that 25% up to 80% of camelids may be infected
D. If infected, most animals eliminate the disease without signs; however, some become asymptomatic carriers. Some animals, especially if immunocompromised, develop symptoms
E. Diagnosis can be made by identifying the parasite on the RBCs in smears or by polymerase chain reaction (PCR)
F. *Mycoplasma haemolamae* can be treated with tetracycline 20 mg/kg once daily × 5 days

III. Alpaca fever
A. A systemic *Streptococcus zooepidemicus* infection
B. Signs include anorexia, recumbency, high fever, pneumonia, pleuritis, peritonitis, and colic
C. Death, which is more common in young animals, occurs in 4 to 8 days
D. Chronic forms may cause mastitis or abscesses
E. Treatment is with broad-spectrum antibiotics such as ceftiofur

IV. Herpesvirus: EHV-1
A. EHV-1 is endemic in horses in the United States and causes rhinopneumonitis and abortion
B. In camelids it is associated with ocular signs, including blindness, loss of pupillary light reflex, retinal degeneration, and optic nerve atrophy
C. Rarely encephalitis may develop

V. *Fusobacterium necrophorum*
A. The most common bacteria associated with tooth root abscesses in camelids
B. Caution must be used in removing teeth because it is easy to fracture their delicate jaw
C. Also causes "foot rot" with interdigital scabs and scales and foot abscesses
D. Treatment: Is usually with penicillin 10,000 international units/lb twice daily × 5 days or another broad-spectrum antibiotic

VI. Contagious ecthyma
A. "Sore mouth" is caused by a pox virus
B. Usually affects crias, causing lesions around mouth and perhaps the dam's udder
C. Unlike sheep and goats lesions may persist for months
D. Zoonotic so caution owners

VII. West Nile virus
A. Most infected camelids develop no symptoms; however, 10% to 83% have positive titers
B. If camelids become ill, signs include "Kathryn Hepburn" type facial or body tremors, ataxia, head shaking, other neurologic signs, fever (50%), recumbency, and death
C. No premortem testing is available at this time for camelids
D. Confirmation is made postmortem
E. Treatment consists of supportive care and possibly plasma transfusions

OTHER COMMON CONDITIONS

I. Heat stress: Hyperthermia
A. Common in camelids in hot, humid areas especially if they are not shorn
B. Normal body temperature is 98.5° to 101.5° F
C. Animals are more prone to heat stress if they are sick, caused to exert themselves, or if the ambient temperature does not allow cooling during the night
D. Initially, there will be a high body temperature, but that is followed by normal or low temperature as body systems shut down
E. Signs include lethargy, tachycardia, tachypnea, dehydration, swelling of testicles and extremities, abortion, acidosis and other electrolyte imbalances, disseminated intravascular coagulation, and death
F. Diagnosis is based on history, signs, and blood work
G. Treatment involves rapid cooling by moving to a cool place or wetting of the nonfibered areas with water or alcohol. Wetting the wool will only insulate the animal and make cooling more difficult. Fluid and electrolyte therapy is indicated,

antiinflammatories, antibiotics for secondary infections, and physical therapy if down for prolonged times

II. Polioencephalomalacia: Thiamine deficiency
 A. The most consistent sign is opisthotonos
 B. Other signs include blindness, listlessness, recumbency, and head pressing
 C. Diagnosis is based on therapeutic response
 D. Can be caused by prolonged amprolium use
 E. Treatment is thiamine

III. Berserk male syndrome
 A. A behavioral condition where males imprint on humans, often when they are orphaned and receive excessive handling as crias. As the males mature, they treat humans as they would other male camelids, often mounting vicious attacks
 B. During a full attack, the berserk male may charge, chest butt, stomp, or bite
 C. Castration does not always resolve this condition
 D. Although some animals have been deconditioned through behavioral training these animals should be considered dangerous
 E. If a male must be hand-raised, owners should avoid loving on the cria and house it with its peers as much as possible

IV. Failure of passive transfer (FPT)
 A. Cria are totally dependent on colostrums for their initial immunity. FPT is common in camelids both as a result of the cria being too weak or premature to nurse and as a result of the dam having insufficient milk at the time of birth
 B. Adequate passive transfer can be evaluated by total protein or by tests specific for immunoglobulin G (IgG)
 C. IgG greater than 800 is considered adequate
 D. Treatment involves administration of camelid plasma, which is commercially available

CAMELID DIGESTIVE DISORDERS

I. Dental problems
 A. Malocclusion: Incisors might not meet the dental pad. This can be fixed by filing the front teeth. Teeth can be filed with OB wire, a Dremel, or a Tooth-a-Matic
 B. Retained incisors: Camelids may retain some or all of their baby teeth
 1. These can usually be pulled with some dental elevation and extraction
 2. A syringe case or a half-role of Elastikon makes a good mouth gag
 C. Tooth root abscesses may result from cutting teeth into pulp or from cracking teeth
 1. Decay may also cause abscessation
 2. Many agents can be involved but *Actinomyces pyogenes* is common
 3. Other reasons for swelling on the jaw may be feed that is stuck in the buccal space
 4. Diagnosis is based on clinical signs and right and left oblique radiographs
 5. Some tooth root abscesses respond well to broad-spectrum antibiotics
 6. Most will need to have the tooth extracted
 a. Extraction of the one or two cheek tooth is possible with small animal instruments
 b. Back teeth are much more difficult and may require repulsion. Be careful not to fracture the jaw

II. Megaesophagus
 A. Most common sign is frequent regurgitation, possibly with weight loss
 B. Contrast radiographs are useful in the diagnosis
 C. The cause is not known
 D. The disease can be managed as for a small animal by feeding small amounts, frequently from an elevated surface

III. Choke
 A. Quite common
 B. Signs include retching, coughing, dysphagia, salivation, and nasal discharge
 C. Fine feeds (crumbles) or rapid eating or fighting over feed may predispose to choking
 D. Many animals respond to external massage or syringing a small amount of water into the mouth to help dislodge the feed
 E. Severe cases may require passing a stomach tube and lavage
 F. Severe cases should be placed on antibiotics to combat aspiration pneumonia

IV. Ulcers
 A. Ulcers are fairly common in any compartment of the stomach
 B. Signs of ulcers include decreased feed intake, crusting and cracking at the corners of the mouth, decreased ruminations, and dry scant feces. The animal is usually depressed and may show a slight tremor, especially at rest. They usually object to abdominal palpation. Fluid around the intestinal loops may be seen on ultrasound
 C. If the lesion has recently perforated, there may be signs of acute colic
 D. Bleeding is rare, so they are often Haemoccult negative
 E. If they have perforated changes associated with peritonitis will be seen on the complete blood cell count
 F. Abdominocentesis is often useful and may show increased fluid or signs of peritonitis, with fecal material, high cell count, and fibrinogen
 G. Gastro-gard has not shown any benefit in controlled studies
 H. Carafate or other gut protectants, such as Pepto-Bismol, may be useful
 I. The animal should be placed on broad-spectrum antibiotics such as Excenel, penicillin, and Gentocin or Baytril
 J. Intravenous (IV) fluids are often necessary to maintain hydration
 K. Flunixin, Valium, or Torbugesic may be helpful in controlling pain

V. Intestinal obstruction
 A. Enteroliths are “normal” in the saccules of C1
 B. Enteroliths elsewhere in the gastrointestinal tract may cause obstruction

C. Signs most often observed include weight loss, intermittent eating, signs of chronic dull pain including tremor, and reluctance to move or get up
D. Obstruction can be caused by phytobezoars, trichobezoars, enteroliths, fecaliths, or foreign objects. They often form at or near the pylorus, and there are at least two cases of gastroliths filling the entire C3 cavity
E. Torsion at the root of the mesentery, intussusception, neoplasia, and abscessation may also cause obstruction
F. Whereas survey radiographs or ultrasound may be suggestive, contrast studies or abdominal exploratory will usually be needed to confirm an intestinal obstruction
G. Abdominal exploratory and enterotomy can be done under injectable anesthesia in field conditions
H. Postoperative animals should be receiving broad-spectrum antibiotics and high-fiber diets

VI. Hepatic lipidosis
A. Causes of hepatic lipidosis vary from starvation to overfeeding
B. Stress from chronic conditions, social interactions, or just "changes" appears to be a major factor
C. Signs are vague and may include inappetence, weight change, poor fiber coat, and occasionally hepatic encephalopathy
D. Icterus is seldom seen
E. Diagnosis will usually be supported by elevated liver enzymes on a profile and possibly an elevated white blood count
F. Liver biopsy may confirm the diagnosis
G. Treatment is supportive. Insulin may help as will a consistent feed supply
H. Antibiotics will help to prevent secondary infections

VII. Enteritis
A. Diarrhea is more common in young crias than in older animals
B. Causes include *E. coli, Salmonella,* clostridial disease, parasites, coccidian, cryptococcus, giardia, and BVD
C. Johne disease would be a consideration in older animals

INTEGUMENTARY SYSTEM

Because of the importance of camelid fiber, there are many important skin conditions in South American camelids. Although any of these conditions can cause disease alone, it is not uncommon for multiple conditions to exist simultaneously. Each must be addressed for successful treatment.

I. Mange
A. South American camelids have been reported to get sarcoptic, chorioptic, and psoroptic mites
B. Signs include crusty, pruritic areas of fiber loss often on the medial thighs, abdomen, chest, perineum, axilla, and between the toes. Facial and ear lesions may also occur
C. Secondary pyoderma is not uncommon
D. Often there may be only one or two animals in the herd showing signs
E. Diagnosis is by skin scrapings, both superficial and deep (between the toes is a good spot) with microscopic identification
F. Treatment is topical insecticides (pyrethrins or organophosphates) or injectable antiparasitics (Ivomec, Dectomax)

II. Lice
A. Both sucking: *Microthorcis cameli,* and biting: *Damalinae breviceps* lice are seen
B. Signs include poor or matted fiber, which lacks strength and luster
C. Affected animals are pruritic
D. Sucking lice can cause anemia
E. Biting lice respond to topical insecticides
F. Sucking lice may be treated with injectable antiparasitics

III. Ringworm
A. Usually *Microsporum* spp. or *Trichophyton* spp.
B. Lesions are often more focal than mange and are crusty, raised, and somewhat circular
C. The face is the most common location
D. Diagnosis based on identification of the fungi with potassium chloride mounts or dermatophyte test medium agar culture
E. Treatment consists of topical iodine scrub and topical fungicidals or systemic antifungals

IV. Bacterial dermatitis
A. *Staphylococcus* spp. and *Dermatophilus congolensis* ("rain scald") have both been isolated from bacterial pyodermas
B. Often seen secondary to other skin conditions
C. Treatment is with broad-spectrum antibiotics, penicillins, or cephalosporins

V. Zinc-responsive dermatitis
A. Zinc deficiency may result in hyperkeratosis
B. Lesions usually affect the bridge of the nose, ears, perineal area, or prepuce
C. Dark-colored animals are affected more often
D. Deficiency may be absolute or due to tying up of zinc by high iron or calcium in the forages or water
E. Serum blood zinc levels in alpacas of 0.6 to 0.75 ppm are considered adequate
F. Levels below 0.5 mg/dL are diagnostic
G. Blood must be handled carefully to avoid laboratory error. Red top stoppers and hemolysis will artificially elevate blood levels. Royal blue stopper tubes are best
H. Treatment is to include 2 g/day of zinc sulfate in the diet or 4 g/day of zinc methionine (ZinPro) in the diet

VI. Insect bites
A. Black flies, other flies, gnats, and mosquitoes can all cause skin irritation
B. Some animals appear more affected than others (dark skin or allergic animals)
C. Lesions are common on areas accessible to insects, such as ears, bridge of the nose, and along the dorsal part in suris

VII. Allergies
A. Some skin conditions in South American camelids have been suspected to be due to allergic reactions. Food allergies, contact and inhalant allergies, and insect allergies have all been suggested

B. Diagnosis includes skin testing or elimination trials
C. Treatment is avoidance of the allergen
D. Steroids should be used with caution, especially in pregnant animals

RESPIRATORY SYSTEM

I. General
 A. Camelids are obligate nasal breathers because of their elongated soft palate, which may rest either dorsal or ventral to the epiglottis
 B. The nasal lacrimal duct opening lies on the floor of the nostril about 0.5 to 1 cm from the opening. It is important because camelids often develop blocked ducts that must be flushed
 C. Choanal atresia: Many forms of craniofacial dysgenesis may occur, but the most common form of birth defect of this type is choanal atresia. The defect may be membranous or bony and may affect one or both nasal passages. Crias with this defect have a characteristic breathing pattern where they inhale and then appear to "swallow" air in an attempt to force it around the elongated soft palate
II. Pneumonia
 A. Bacterial pneumonia is fairly uncommon in camelids but can occur
 B. Agents include tuberculosis, actinobacillosis, pasteurella, and fusobacterium
 C. Fungal diseases such as coccidioidomycosis (San Joaquin Valley fever) can affect the lungs and other organs if the animal is from an endemic area
 D. Viral causes of pneumonia have not been well described

REPRODUCTIVE SYSTEM

I. Reproductive cycle
 A. South American camelids are induced ovulators
 B. They do not have an estrus period
 C. Females are generally receptive to a male anytime after they reach puberty unless they are pregnant or have been recently bred
 D. They have follicular waves, which overlap and occur every 7 to 12 days
 E. Follicles 7 to 12 mm in size are considered breedable, and the female will ovulate with sufficient stimulation
 F. In North America they show no seasonality to their cycles
 G. Once induced to ovulate, females will stay nonreceptive for a period of 9 to 14 days (luteal phase) and then, if not pregnant, she will become receptive again
 H. Camelids have four teats
II. Breeding
 A. Virtually all camelid breeding occurs naturally to ensure induction of ovulation
 B. When placed together, the male will chase the female and attempt to mount her
 C. If the female is receptive, she will lie down in sternal recumbency. If she is nonreceptive, she will continue to run and "spit" the male off
 D. The male will then breed the receptive female by mounting her from the rear while they are both in sternal recumbency
 E. Breeding will generally last 5 to 50 minutes, with the male vocalizing or "orgling" the entire time
III. Pregnancy
 A. Although ovulation occurs off both ovaries, most pregnancies (90%) implant in the left horn
 B. Early embryonic death is common in camelids and may be as high as 50% before day 90
 C. Gestation is quite variable, usually 335 to 360 days but may go longer than a year
 D. Twinning is rare and usually results in abortion
 E. Pregnancy may be determined by the following:
 1. Behavior ("spitting off")
 2. Progesterone analysis (greater than 1 ng/mL at day 21)
 3. Rectal palpation, especially in larger llama
 4. Ultrasonography
 F. The placenta is diffuse epitheliochorial
 G. South American camelids have an extra membrane, the epidermal membrane that is attached to the fetus at the mucocutaneous junctions
IV. Birthing
 A. There are three stages to camelid birthing, as with other species
 B. Most female camelids deliver during daylight hours
 C. Stage 1: Cervical dilation may last 2 to 6 hours, and females show discomfort, humming, frequent trips to the dung pile
 D. Stage 2: Delivery generally lasts less than 30 minutes. Deliveries longer than 30 minutes generally result in a dead fetus
 E. Stage 3: Passage of the placenta should require less than 2 hours
 F. Dystocia, although not common, may happen. It may be due to malposition of the head or limbs but more commonly results from fetomaternal mismatch

REPRODUCTIVE DISEASES AND CONDITIONS

I. Persistent corpus luteum
 A. Open female will remain nonreceptive
 B. Diagnosis by high progesterone level, ultrasound, or both
 C. Treatment prostaglandin
 1. Lutalyse caution: There are reports of lutalyse causing death in camelids
 2. Estrumate is more commonly used, 1 cc administered intramuscularly (IM) each day × 2 days
II. Uterine torsion
 A. Uterine torsion is fairly common in camelids and may occur anytime in the third trimester, especially in the last 4 weeks
 B. Females display signs of abdominal pain, kicking, straining, frequent lying down, and getting up
 C. Diagnosis is made by seeing twisting on vaginal speculum examination or by palpation

D. Most camelid torsions can be corrected by rolling the dam while pressure is applied to the abdomen to hold the uterus in place

III. Retained placenta
A. More than 2 to 3 hours can lead to infection and sepsis
B. Treatment is oxytocin 20 to 30 international units IM or by continuous-drip IV
C. If retained longer than 24 hours, treat as you would a mare, with systemic antibiotics and antiinflammatories

IV. Metritis
A. Uterine infection is thought to be a common cause of infertility in camelids
B. Toxic metritis appears to be uncommon
C. Metritis is often thought to be the result of overbreeding as the male penetrates deep into the uterine horns
D. Bacterial agents include *E. coli*, *Staphylococcus aureus*, *Streptococcus zooepidemicus*, *Streptococcus* spp., *Pseudomonas aeruginosa*, *A. pyogenes*, and yeast
E. Treatment includes systemic antibiotics, ceftiofur or uterine flushing through an indwelling catheter with dilute betadine, antibiotics, or plasma

V. Abortion
A. Although early embryonic death or abortion is more common in camelids than in other livestock, infectious causes are seldom incriminated
B. Agents that have been reported to cause abortions are *Brucella* spp., *Listeria* spp., chlamydiae, toxoplasmosis, leptospirosis, and neospora
C. Camelids appear to be very sensitive to corticosteroids; even topical application may cause abortion
D. Heat stress, general stress, and twinning can also cause abortion

COMMON CONGENITAL CONDITIONS

Nearly all the same birth defects that occur in other species can occur in camelids. A couple of the conditions that happen commonly are discussed below.

It is important to note that *congenital* does not always indicate *hereditary*. Although several defects in camelids are suspected to be hereditary, few studies have been conducted to prove this.

I. Angular limb deformity
A. May affect front or rear limbs, with one or more joints involved
B. Often present at birth but may also result from rickets or lack of sunshine and vitamin D deficiency (long cloudy winter months in Northern climates)

II. Choanal atresia
A. Common; refers to a membranous or osseous barrier between the nasal and pharyngeal passages
B. May be partial or complete, unilateral or bilateral
C. Results in death if it is complete as camelids are obligate nasal breathers
D. Crias show a characteristic breathing pattern where they stand with their neck extended, fill their cheeks with air, close their mouth, and compress their cheeks to force air around the elongated soft pallet into the trachea. They must then also push air out of their lungs to exhale

III. Other common defects
A. Luxation of the patella
B. Arthrogryposis
C. Crooked tail
D. Hemivertebrae
E. Facial deformities: Shortening, jaw malformation, cleft palate
F. Cardiovascular defects: Ventriculoseptal defect, atrial septal defect, patent ductus arteriosus, tetralogy of Fallot

Supplemental Reading

Smith BP. *Large Animal Internal Medicine*, 4th ed. St Louis, 2009, Mosby.

Youngquist RS, Threlfall WR. *Current Therapy in Large Animal Theriogenology*, 2nd ed. St Louis, 2007, Saunders.

Ovine/Caprine Medicine and Management

51 CHAPTER

Natalie J. Coffer

HUSBANDRY

I. Behavior
 A. Sheep
 1. Exhibit strong flocking behavior and follow one another. Separating a sheep from the flock can cause signs of agitation and stress
 2. Natural flight response can be used to the handler's advantage to move them into races, chutes, or small pens for examinations or procedures
 3. They are easily excitable. Handlers should move and restrain animals in such a way as to avoid excessive stress
 4. Sheep observed to separate themselves from the rest of the flock or fail to keep up with the flock when being moved should be inspected for signs of illness
 5. Fighting or challenging behavior includes snorting, stamping the foot, and head-butting
 B. Goats
 1. Exhibit herding behavior, and isolation from the herd can induce considerable stress. Goats have gregarious and inquisitive natures and, when handled frequently, can become companion animals
 2. Goats that lag behind the herd when moving or isolate themselves from the herd should be inspected for signs of disease
 3. Goats like to climb and will scale rocks and trees and, if given the opportunity, cars and farm equipment
 4. Fighting behavior includes rearing on hind legs and head-butting

II. Management
 A. Sheep
 1. Raised for meat, wool, and milk. Flock management systems can vary depending on many factors, including desired end-product, lambing frequency, lambing season, and regional climate
 2. Sheep kept on pastures need access to shelter in inclement weather. Periparturient ewes should be housed in smaller pens to allow close monitoring for parturition problems. If possible, lambing stalls should be provided to facilitate bonding with lambs
 3. Regular pasture rotation should be part of any management system to reduce the build-up of internal parasite larvae on pastures
 B. Goats
 1. Raised for meat, fiber (hair), and milk
 2. Need access to grazing and browsing areas. Goats kept at pasture need access to shelter in inclement weather. As with sheep, close monitoring near parturition and kidding pens are recommended for goats
 3. Anthelmintic resistance is a significant problem in goat herd management worldwide. Strategic anthelmintic use, alternative parasite control methods, and regular pasture rotation are essential to control internal parasite infestations and prevent further development of anthelmintic resistance

III. Nutrition
 A. Sheep: Grass and roughage grazers
 B. Goats: Browsers and grazers. Prefer varied diet. Often used for brush management
 C. Rumen microbe fermentation of forage and other feedstuffs provides energy for the ruminant in the form of volatile fatty acids (VFAs), mainly acetic, propionic, and butyric acids. Roughly 50% of available energy in the ruminant diet is provided in form of VFAs. Digestion of microbial tissue provides proteins and essential amino acids
 D. Most flocks of sheep and goats in United States are maintained on pasture- or range-based systems. In general, roughly 80% of diet of sheep and goats is from forage
 E. Good nutrition for sheep and goats can be maintained with many perennial grasses. Legumes, annual grasses, and prudent grain supplementation can be added. Oversupplementation with alfalfa, grain, or both can lead to rumen acidosis, bloat, and urolithiasis
 F. A minimum of 7% crude protein is required for normal rumen flora growth and function. Dietary protein content should vary depending on stage of growth, weight-gain goals, and lactation or pregnancy status
 G. Digestible energy and nutrient requirements can vary depending on stage of growth, reproductive status, and production goals
 H. Mineral deficiencies and toxicities can occur when macrominerals or microminerals in the diet are improperly balanced
 1. High phosphorus content can lead to urinary calculi formation. To prevent urolithiasis, a calcium-to-phosphorus ratio of 2:1 or more should be maintained

2. Selenium-deficient areas need selenium supplementation in sheep and goat diets. Inappropriate supplementation can lead to toxicity
3. Sheep are more susceptible to copper toxicity than are other ruminants and horses because of their increased efficiency in retaining copper. Goats are more resistant to copper toxicity than sheep
 a. Dietary copper levels should not exceed 10 parts per million (ppm)
 b. Copper deficiencies in pregnant ewes can lead to enzootic ataxia in lambs. Minimum of 5 ppm dietary copper is recommended
 c. Secondary copper deficiency can occur with high levels of molybdenum
4. Hypocalcemia or milk fever can occur in prepartum or postpartum sheep or goats with multiple neonates

RESTRAINT AND HANDLING

I. Physical examination of small ruminants should begin with observation from a distance, preferably in the animal's normal environment whenever possible
 A. Observe interaction with herd mates, behavior, response to environmental stimuli, respiratory pattern, fleece or hair condition, posture, and gait
 B. Further examination requires proper restraint
II. Restraint
 A. Sheep
 1. After moving into race or small pen, sheep can be grabbed by the mandible and tail or caught by crook or lariat (Figure 51-1)
 2. Wool should not be grabbed to restrain sheep. May result in damage to fleece
 3. Handler should stand to the side of the sheep and put one hand under the mandible and one on the tail or under the flank. Sheep may be positioned on rump for examination, foot trimming, or shearing
 B. Goats
 1. Can be restrained by catching and holding the goat's neck, beard, mandible and tail, or base of horns. Grabbing the tip of horns may cause fracture of horn or skull
 2. May be restrained by holding the head and straddling the withers or neck or by holding the goat against a wall or fence (Figure 51-2)
III. Body condition score (BCS)
 A. Sheep
 1. Heavy fleece may conceal the BCS. Must palpate fat and muscle around the dorsal and transverse spinous processes of lumbar vertebrae
 2. Scoring system ranges from 1 (emaciated) to 5 (obese)
 3. Monitoring BCS is one aspect of monitoring flock health
 a. Especially important to monitor BCS during breeding and parturition to ensure that ewes are not overconditioned or underconditioned
 b. Inappropriate BCS can lead to a variety of reproductive insufficiencies and periparturient diseases
 B. Goats
 1. Scoring system ranges from 1 to 5
 2. Similar to sheep



Figure 51-1 The handler is on the left side of the sheep with his left hand under the jaw and his right hand holding the tail. It would be acceptable for him to be kneeling with one knee (usually the right) on the ground and the right hand holding the right rump. (From Pugh DG. *Sheep & Goat Medicine*. Philadelphia, 2002, Saunders.)***



Figure 51-2 Goats can be restrained by their horns if the handler grasps near the skin and keeps the rear of the animal under control. If the handler does not control the animal's rear and the goat flips around, it may injure its neck. Grasping the horn near the tip may result in breaking the horn and possibly fracturing the skull. (From Pugh DG. *Sheep & Goat Medicine*. Philadelphia, 2002, Saunders.)

MEDICAL DISORDERS

I. Upper gastrointestinal (GI) disorders
 A. Complete physical examination should include oral examination
 B. Normal dental formula for adult sheep and goats: 2 (incisors 0/3, canines 0/1, premolars 3/3, molars 3/3) = 32 teeth
 C. Oral cavity should be inspected for broken, loose, or missing teeth; uneven wear; foul odor; swellings on mandible or maxilla; labial, lingual, or buccal abnormalities or injuries; foreign bodies; and lingual and pharyngeal function
 D. Actinomycosis
 1. "Lumpy jaw"
 2. Caused by *Actinomyces bovis*, gram-positive rods
 3. Chronic, suppurative granulomatous infection of bony and soft tissue structures of oral cavity
 4. Successful treatment includes early antimicrobial therapy and surgical debridement
 E. Actinobacillosis
 1. *Actinobacillus lignieresii*
 2. Pleomorphic, facultative anaerobic gram-negative rod bacteria
 3. Infections result in granulomatous abscesses in soft tissues of oral cavity, larynx, and associated lymph nodes
 4. Involvement of the tongue known as "wooden tongue"
 5. Inoculation of mucosal tissue may result after injury from coarse feeds
 6. May spread hematogenously or via lymphatics to other sites
 7. Successful treatment requires early aggressive antimicrobial therapy and surgical debridement
 F. Tooth-root abscesses
 1. Presents as swelling on mandible or maxilla. Draining tracts often present. Affected tooth may be loose on palpation; gingival swelling may be noted
 2. Radiographs may confirm diagnosis with the presence of bony lysis around the tooth root
 3. Extraction of affected tooth, debridement of affected bone, and antimicrobial therapy are often indicated
 G. Contagious ecthyma
 1. Parapox virus; zoonotic
 2. Orf: Sore mouth
 3. Clinical signs include vesicles on mucocutaneous junction of lips and nose. Erupted vesicles result in ulcerated mucosa and scabs. Lesions also occur on udder, coronary bands, and eyelid margins
 4. Young animals are more severely affected; painful oral lesions often interfere with nursing
 5. Vaccination with live virus may reduce the frequency of outbreaks in affected herds. Use of vaccine is often regulated by state officials
 6. Virus may remain viable in the environment for extended periods. Elimination from affected herds is challenging
 H. Bluetongue virus
 1. RNA orbivirus is transmitted by *Culicoides*
 2. Ulcerative lesions appear on oral mucosa, muzzle, and lips as well as erythema and edema. Coronitis and diffuse dermatitis can also occur. Exposure of ovine fetuses to the blue tongue virus can result in hydrancephaly and other developmental abnormalities
 3. Hyperemia and swelling of the muzzle, lips, and ears and cyanosis of the tongue may occur
 I. Foot-and-mouth disease
 1. Reportable disease
 2. Caused by highly contagious ribonucleic acid (RNA) picornavirus, genus *Apthovirus*
 3. Spread by aerosol and mechanical vectors
 4. High morbidity, low mortality disease
 5. Lesions form on skin and mucous membranes 2 to 14 days post exposure. Vesicles appear, and rupture results in erosions in the skin. Secondary bacterial infection may follow
 6. Characteristic lesions occur on lingual, nasal, and buccal tissue; interdigital skin; coronary bands; and teats
 7. Infection may be undetectable in sheep and goats and therefore may be virus carriers and amplifiers
 J. Reportable disease caused by rhabdovirus
 K. Sheep and goat pox
 1. Reportable disease
 2. Caused by two related poxviruses
 3. Transmitted by aerosol, direct contact, and mechanical vectors
 4. Can persist for long periods in environment
 5. Erythema and papular pox lesions occur on oral, nasal, and ocular mucous membranes. Respiratory tract and peritoneal cavity may also be affected
 6. Fever and upper respiratory signs can occur initially
 L. Megaesophagus: Reported in Alpine and Nubian goats and Southdown sheep. May be associated with *Sarcocystis* spp.

II. GI diseases
 A. Diagnostic tests
 1. Rumen fluid analysis
 2. Abdominocentesis
 3. Fecal examination
 4. Radiography-ultrasonography
 5. Exploratory laparotomy
 B. Bloat
 1. Free gas bloat
 a. Accumulation of fermentation gases in rumen
 (1) Due to excessive production with high-grain diets
 (2) Due to failure of eructation with esophageal dysfunction or obstruction
 b. Clinical signs include abdominal distension and filling of left paralumbar fossa
 c. Respiratory distress and death by respiratory failure may occur if left untreated

d. Treatment includes passing of orogastric tube to decompress rumen. Trocarization of rumen or emergency laparotomy may be indicated in cases of severe respiratory distress

2. Frothy bloat
 a. Rumen fermentation gases trapped in stable foam
 b. Can occur with consumption of legumes, lush cereal grain grasses, and high-concentrate rations
 c. Passing of orogastric tube often does not decompress rumen. Intrarumenal administration of poloxalene or mineral oil may help disrupt foam and release gas
 d. Prevention measures include slow introduction to legumes and high-grain diets and supplementing with poloxalene, monensin, or lasalocid

C. Rumen acidosis
 1. Resulting from overconsumption of rapidly fermentable carbohydrate feeds
 2. Rumen pH drops, allowing lactic acid–producing bacteria to proliferate. A further drop in rumen pH results in death of rumen protozoa and lactic acid users
 3. Systemic lactic acidosis and dehydration are sequelae
 4. Rumen lavage via nasogastric tube or rumenotomy is often indicated
 5. Acidic pH of rumen fluid can damage rumen mucosal lining, resulting in rumenitis. Translocation of bacteria and toxins into portal and systemic circulation may occur. Loss of rumen flora production of thiamine can lead to polioencephalomalacia (PEM)

D. Abomasitis and abomasal ulcers
 1. Causes include rumen acidosis, infectious causes, finely ground or pelleted feeds
 2. Clinical signs include melena, reduced appetite, and bruxism

E. Abomasal emptying defect in sheep
 1. Described in Suffolk sheep
 2. Characterized by weight loss, loss of appetite, and abdominal distension
 3. Clinical pathology changes typical of abomasal obstructive disease: Elevated rumen chloride, serum hypochloremia, metabolic alkalosis, and hypokalemia
 4. Undetermined cause. Medical and surgical treatment often unsuccessful

F. Neonatal diarrhea in kids and lambs
 1. Multifactorial disease complex influenced by environmental factors, infectious agents, nutrition, and immune status of the neonate
 2. Important infectious causes of neonatal diarrhea include enterotoxigenic *Escherichia coli* (ETEC), *Cryptosporidium* spp., rotavirus, *Salmonella* spp., and *Giardia* organisms
 a. ETEC
 (1) Occurs in lambs and kids less than 10 days old, commonly in neonates 1 to 4 days of age
 (2) Pathogenesis mediated by two virulence factors, fimbria K99 and F41, and enterotoxin. Enterotoxin-mediated diarrhea causes hypersecretion of fluids and electrolytes, resulting in dehydration, acid-base imbalance, and electrolyte deficiencies in the affected animal. Septicemia can also occur
 (3) Fecal culture and serotyping of fimbriae support diagnosis
 (4) Treatment involves supportive care, including oral or fluid therapy, nonsteroidal antiinflammatory drugs (NSAIDs), and systemic antimicrobials if septicemia is suspected
 (5) Preventative measures include good hygiene in lambing and kidding areas and periparturient vaccination of ewes and does with a bovine ETEC vaccine
 b. *Cryptosporidium parvum* spp.
 (1) Causes diarrhea in lambs and kids 5 to 10 days of age
 (2) Zoonotic disease
 (3) Protozoal parasite that infects villus tips of intestinal enterocytes, resulting in malabsorptive diarrhea
 (4) Oocytes are immediately infective. Sporulation can occur within intestine, resulting in autoinfection. Disease course can therefore be prolonged
 (5) Diagnosis is confirmed via acid-fast staining of fecal smears. Fecal floats are less reliable (Figure 51-3)
 (6) Treatment consists of supportive care. Infection can be self-limiting
 (7) Isolation of affected animals and good hygiene can prevent spread of disease
 c. Rotavirus
 (1) Group B virus affects lambs and kids
 (2) Animals 2 to 14 days old are most commonly affected. Older animals can be affected

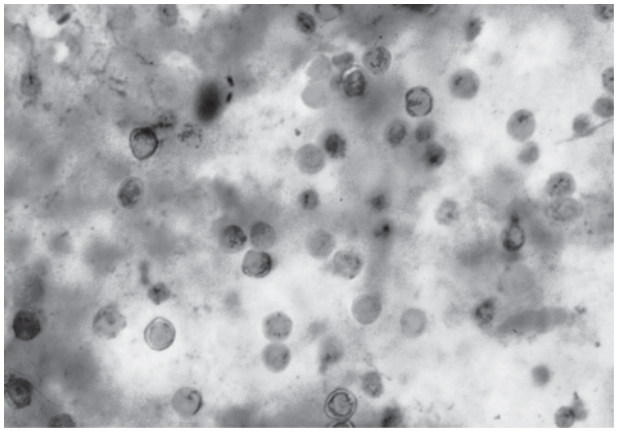


Figure 51-3 Red-staining *Cryptosporidium* on a blue-green background in a fecal smear prepared with an acid-fast stain. This protozoal parasite induces villous atrophy and decreased digestion. (From Pugh DG. *Sheep & Goat Medicine*. Philadelphia, 2002, Saunders.)

(3) Tips of intestinal villi are infected with virus and sloughed. Malabsorptive diarrhea results in dehydration and depression
(4) Diagnosis supported by finding rotavirus particles by electron microscopy of fecal samples
(5) Treatment is supportive care

d. *Salmonella* spp.
(1) Causes diarrhea in lambs and kids of any age. High mortality and morbidity in neonates younger than 1 week
(2) Zoonotic disease
(3) Causes acute and chronic enteritis and colitis, pneumonia, septicemia, and other syndromes
(4) Causes invasive enteritis and severe inflammation and necrosis of small and large intestine. Diarrhea caused by *Salmonellosis* is often characterized by blood and mucosal shreds
(5) Diagnosis is confirmed by fecal culture, polymerase chain reaction techniques or identification of organism on histopathologic examination of intestine
(6) Treatment consists of supportive therapy. Antimicrobial administration is indicated in cases of septicemia

e. *Giardia* spp.
(1) A flagellated protozoan parasite that causes diarrhea in 2- to 4-week-old lambs and kids
(2) Diarrhea is often transient, and infection can be self-limiting
(3) Affected animals may shed cysts for long periods

G. Diarrhea in older lambs and kids
1. Biotypes A-D clostridial enterotoxemia
a. Caused by colonization of GI tract and rapid proliferation of *Clostridium perfringens*, an anaerobic, spore-forming rod
b. Type A enterotoxemia
(1) Soil inhabitant and normal GI commensal in some animals
(2) Can produce high levels of α-toxin, a phospholipase that can cause hemolysis, increased vascular permeability, and villous necrosis in GI tract
(3) Clinical signs include icterus ("yellow lamb disease"), fever, lethargy, anemia, hemoglobinuria, and rapid death

c. Type B enterotoxemia
(1) Produces α-toxins, β-toxins, and ϵ-toxins. Causes hemorrhagic necrotic enteritis ("lamb dysentery")
(2) Rarely seen in North America
(3) High morbidity and mortality, near 100%

d. Type C enterotoxemia
(1) Sudden dietary changes or disruption of normal GI flora can allow overgrowth of normal GI commensal *C. perfringens* and production of α-and β-toxin
(2) Pathogenesis mediated primarily by β-toxin
(3) Clinical signs include depression, diarrhea, nervous signs, and sudden death
(4) Hemorrhagic necrosis of jejunum and ileum seen at postmortem. Nervous signs may include tetany and opisthotonos in lambs
(5) High mortality, nearly 100%
(6) Known as "struck" in adult sheep
(7) Multivalent vaccines available for prevention of diseases in ruminants

e. Type D enterotoxemia
(1) Associated with high-energy diets or sudden changes in diet resulting in normal GI commensal *C. perfringens* overgrowth and production of ϵ-toxin ("overeating disease")
(2) Can occur in sheep of any age. Most commonly seen in lambs 3 to 8 weeks old. Commonly lambs of heavily lactating ewes
(3) Clinical signs include depression, nervous signs, hyperglycemia, glucosuria, sudden death. Postmortem signs include small areas of hemorrhage on GI mucosa, edema of various organs, especially kidneys ("pulpy kidney disease"), resulting from the ability of epsilon toxin to increase mucosal permeability
(4) Nervous signs include opisthotonos, ataxia, muscle tremors, seizures
(5) High mortality rate. Death can occur within hours
(6) Multivalent vaccines are available for prevention of diseases in ruminants

2. Coccidiosis
a. One of the most economically important diseases in livestock
b. Common cause of diarrhea in weanling lambs and kids. Also occurs in young lambs and kids younger than 3 to 4 weeks of age. Occurs less commonly in adults. Subclinical infections can be a cause of poor weight gain and production losses
c. Frequently associated with crowded conditions and intensive husbandry
d. Protozoan parasite (*Eimeria* spp.) that invades and replicates in intestinal villi
e. Coccidia are species specific. Sheep and goats can be host to several species of *Eimeria*. Pathogenic species for sheep include *E. ahsata* and *E. ovinoidalis*; for goats, *E. ninakohlyakimovae*, *E. arloingi*, and *E. christenseni*
f. Infection occurs by fecal-oral transmission. After ingestion of sporulated oocytes, parasite completes asexual and sexual phases of life cycle in enterocytes. Rupture of villi epithelium leads to GI mucosal damage and clinical signs of diarrhea. Prepatent period is 21 to 28 days

g. Can cause acute or chronic disease. Clinical signs include diarrhea, weakness, weight loss, anorexia, poor weight gain and growth, poor hair coat, and death. Clinical pathology may indicate anemia and hypoproteinemia
h. Diagnosis confirmed by detection of oocytes in fecal samples of animals exhibiting clinical signs
i. Treatment and prevention include use of coccidiostats, which can be added to feed or water. Severely affected animals may need supportive care. Reducing stocking density, improving hygiene, cleaning and disinfecting between groups, and separating sick animals can help reduce incidence of disease

H. GI parasites
1. Coccidiosis (see above)
2. GI nematodes
a. Major cause of disease and economic loss in sheep, goats, and camelid production
b. Strongylid species are most significant GI nematodes; found in stomach and intestine. Other nematodes may be found in small and large intestine but are not major pathogens
(1) *Strongyloides*, *Aoncotheca* (formerly *Capillaria*) in small intestine
(2) *Trichuris* in large intestine
c. Strongylid species that contribute to small ruminant parasitic gastroenteritis include: *Haemonchus contortus*, *Telodorsagia circumcinta*, *Trichostrongylus axei*, *Nematodirus* spp., and *Cooperia* spp.
d. Diagnosis of GI nematodes is by fecal floatation for detection of parasite eggs. Eggs of strongylid species are similar in appearance. Fecal culture and larval identification are required to differentiate parasite genera
e. *Haemonchus contortus*, the "barber pole worm," is the most significant GI nematode in small ruminants
(1) Abomasal parasite
(2) Adults and L4 feed on host blood. Infections in large numbers can result in severe, life-threatening anemia
(3) Female worms can produce thousands of eggs per day. Rapid accumulation of larvae on pastures can occur
(4) Resistance to three classes of anthelmintics used in small ruminants (benzimidazoles, cholinergic agonists, and macrocyclic lactones) is widespread
(5) Alternative methods of parasite control such as pasture rotation, selective or strategic deworming, and mixed livestock grazing are becoming more important
f. Strongylid species undergo *hypobiosis,* or a period of arrested development, within the host to aid survival
3. Trematodes
a. Liver flukes *Fasciola hepatica* and *F. magna* occur in the United States and can cause enteritis and death in sheep and goats
b. Intermediate hosts are the land snail and brown ant
c. Metacercariae ingested from pasture by livestock excyst in the small intestine. Flukes migrate to liver parenchyma. Adults produce eggs in bile ducts. Migration through liver parenchyma can cause extensive damage and death
d. Diagnosis
(1) History of grazing in affected areas, clinical signs of liver disease or liver failure, changes in serum chemistry profile (i.e., elevated γ-glutamyl transpeptidase and serum glutamate dehydrogenase concentrations, anemia, and hypoproteinemia)
(2) In chronic infestations, fluke eggs may be found in fecal samples
(3) Immature flukes in liver parenchyma, parasitic tracts, hepatic fibrosis and hemorrhage, distended bile ducts at necropsy
e. Treatment: Administration of flukicides effective against juvenile and adult stages of parasite
f. Prevention
(1) Graze stock away from snail habitats
(2) Regular use of flukicides in affected areas
(3) Use of molluscicides in affected areas
4. Cestodes
a. Tapeworm species of genus *Moniezia* affects small ruminants
b. Infestation occurs with consumption of intermediate host, orbatid mites
c. Rarely cause disease in ruminants unless present in large numbers
d. Diagnosis based on demonstration of tapeworm segments in feces or in perineal region
e. Treat with anthelmintics labeled for cestodes

I. Johne's Disease
1. Chronic wasting disease caused by *Mycobacterium avium* subspecies *paratuberculosis*. Granulomatous enteritis of the small intestine is the characteristic lesion
2. Depression and severe chronic weight loss are common clinical signs in small ruminants. Unlike in cattle, diarrhea is uncommonly a clinical feature in sheep and goats
3. Infection occurs by consumption of contaminated feed, milk, or water. Infection may occur in utero in late stages of disease. Young stock can become infected by suckling infected dams as the bacterium is excreted into milk, although clinical signs might not become apparent for years
4. Diagnosis is supported by clinical signs, serum agar gel immunodiffusion (AGID) test, fecal culture, or acid-fast stain of fecal sample. *M. avium paratuberculosis* is a fastidious organism; thus fecal culture may take 6 to 8 weeks or longer.

Granulomatous tissue reaction in small intestine is not as prominent in sheep and goats as it is in cattle. Main postmortem feature is emaciation. Examination of intestinal mucosa with acid-fast staining can confirm diagnosis

5. Prevention and control
 a. No effective treatment exists. Animals that have tested positive should be culled. Young stock should not be allowed to consume colostrum from infected adults
 b. Introduction of infected animals into a herd can be prevented by operating a closed herd or buying animals from a herd that has tested negative for Johne within the previous 12 months

J. Rectal prolapse
 1. Prolapse of rectal mucosa
 2. Occurs with the following:
 a. Excessive straining with diarrhea
 b. Males with urolithiasis
 c. Extreme tail docking
 d. Chronic coughing
 3. Surgical correction is often indicated

K. Diseases of the liver
 1. Pregnancy toxemia
 a. Metabolic disease resulting from energy imbalance; commonly seen in ewes in late gestation or pregnancy with multiple fetuses
 b. Pregnant, obese, or thin ewes suffering from a prolonged negative energy balance are often affected
 c. Increased energy demands of rapid fetal growth in late pregnancy in conjunction with reduced intake resulting from reduced rumen capacity, poor management or concurrent disease results in a negative energy balance. Hypoglycemia, ketonemia, ketonuria, and hypocalcemia ensue
 d. Fatty liver syndrome may occur in conjunction with this disease
 e. Clinical signs include anorexia, depression, weakness, neurologic deficits (ataxia, blindness), and recumbency. Fetal death may also occur. If left untreated, death of the ewe may occur within a few days of onset of clinical signs
 f. Treatment: Supportive care for the ewe should include intravenous (IV) glucose supplementation or oral propylene glycol therapy to restore positive energy balance. Correction of electrolyte deficiencies and acid-base balance is essential. Transfaunation may be indicated to increase appetite. Removal of fetal energy drain by inducing parturition or by cesarean section is often indicated
 g. Prevention: Management techniques to avoid a herd problem with pregnancy toxemia include ensuring access to feed, good nutrition for pregnant ewes, and reduction of environmental stress. Ultrasonography can be used to identify ewes pregnant with multiple fetuses to provide an increased plane of nutrition. Monitoring serum β-hydroxybutyrate concentrations may help identify ewes in negative energy balance before the onset of clinical signs
 2. Liver flukes (see above)
 3. Copper toxicosis
 a. Dietary copper is needed for iron absorption and hemoglobin formation. Sheep are more susceptible to toxicosis than goats or cattle. Consumption of cattle feeds or supplements by sheep can lead to copper toxicity
 b. Acute and chronic forms of toxicosis can occur. Consumption of soluble copper salts can lead to acute toxicity. Ingestion of copper in excess of molybdenum can lead to chronic accumulation of copper in the liver
 c. Excessive accumulation of copper can lead to signs of liver disease. Sudden release of hepatic copper stores can result in an acute hemolytic crisis. Acute crises may be brought on by stress
 d. Clinical signs of copper toxicosis include depression, anorexia, weakness, and diarrhea. Evidence of an acute hemolytic crisis include anemia, hemoglobinuria, hemoglobinemia, icteric or muddy brown mucous membranes. Additional clinicopathologic abnormalities include azotemia and elevated liver enzymes
 e. Clinical diagnosis can be confirmed with elevated serum copper concentrations, which may increase 10- to 20-fold in an acute hemolytic crisis (range 50 to 200 μg/dL). Postmortem diagnosis can be confirmed by examination of renal or hepatic tissue for elevated copper concentrations
 f. Treatment is often unsuccessful. Supportive care addressing hemolytic crisis should be implemented. Other medications administered to help reduce body stores of copper include ammonium molybdate, sodium thiosulfate, ammonium tetrathiomolybdate, and D-penicillamine
 g. Preventative measures include avoiding dietary copper levels higher than 10 ppm and a ratio of copper to molybdenum greater than 10:1. Molybdenum binds dietary copper and prevents chronic copper accumulation in hepatic tissue. Adding molybdenum to achieve a dietary ratio of Cu to Mo of 6:1 to 8:1 has been recommended

III. Cardiovascular diseases

A. Examination of the cardiovascular system
 1. Examination should include auscultation of the heart for abnormalities in rate, rhythm, and blood flow
 2. Mucous membrane color, vasculature, and perfusion should be assessed by examination of conjunctival, scleral, vulval, and buccal membranes
 3. Strength of peripheral pulses and synchronization with cardiac contractions can be assessed by palpation of peripheral arteries, including the femoral and brachial arteries

4. Further evaluation of the cardiovascular system can be achieved with thoracic radiography, electrocardiography, and echocardiography

B. Congenital cardiac disease
 1. Most commonly observed congenital heart defect in sheep and goats is a ventriculoseptal defect (VSD)
 a. VSD is a communication between the right and left ventricles through the interventricular septum. Clinical signs may vary depending on size of the defect in the septum, direction of the blood, and the concurrent presence of other cardiac disease
 b. Clinical signs include a pansystolic heart murmur, often bilateral, with postmortem interval on the right side of the thorax over the tricuspid valve. Signs of cardiac insufficiency that may be observed include failure to thrive, exercise intolerance, lethargy, and weakness
 2. Other cardiac defects that occur in sheep and goats are patent ductus arteriosus, atrial hypoplasia, cardiomegaly, atrial septal defect, and tetralogy of Fallot

C. Acquired cardiac disease
 1. Nutritional myodegeneration (white muscle fisease)
 a. Cardiomyopathy of neonates in first week of life. Skeletal form of disease also occurs
 b. Attributed to deficiency of selenium or vitamin E. Disease in neonates is often due to selenium-deficient gestational diet of dams
 c. Cardiomyopathy can lead to cardiac and respiratory failure. Lesions in diaphragmatic and intercostal muscles contribute to respiratory failure. Death can occur within 24 hours of onset of respiratory signs (i.e., dyspnea, tachypnea, weakness, and foamy or blood-tinged nasal discharge). Additional signs of cardiomyopathy include tachycardia, heart murmurs, and arrhythmias
 d. Whole blood and plasma can be analyzed for low levels of selenium and vitamin E, respectively, to confirm clinical diagnosis. Low liver stores of selenium and characteristic white streaks and pale areas of muscle fibers confirm the postmortem diagnosis
 e. Treatment is often unsuccessful. Supportive care and parental administration of selenium and vitamin E are indicated
 f. Sufficient dietary selenium (0.1 to 0.3 ppm) for dams is recommended to prevent white muscle disease in neonates. Late gestation parental supplementation of vitamin E and selenium may be indicated
 2. Bacterial endocarditis
 a. Vegetative lesions develop on cardiac valves, resulting in valvular insufficiency and cardiac dysfunction. Lesions can form as a result of bacterial invasion and inflammation
 b. Often associated with chronic active infections such as rumenitis, liver or foot abscesses, or bacterial infections that may promote bacteremia. Commonly isolated organisms are *Arcanobacter* (*Actinomyces*) *pyogenes* and α-hemolytic *Streptococcus* spp.
 c. Animals may be asymptomatic in early stages of disease. A heart murmur may be associated with the affected valve(s) often ausculted. Valvular insufficiency may lead to signs of cardiac dysfunction and congestive heart failure in the chronic form of the disease. Intermittent fever and weight loss are often notable clinical signs
 d. Echocardiography is required for definitive antemortem diagnosis. Presumptive diagnosis is supported by clinical signs of cardiac murmur, positive blood culture results, and clinical pathological findings consistent with inflammation (elevated neutrophil count, globulin and fibrinogen levels, and a nonregenerative anemia)
 e. Chances for successful outcome improve when treatment is initiated in early stages of the disease. Long-term therapy with broad-spectrum antibiotics is indicated for bacterial endocarditis. Prognosis is poor to grave after signs of cardiac dysfunction or congestive heart failure develop
 3. Ionophore toxicity
 a. Ionophores are antimicrobials that are often added to feed or water as coccidiostats and growth promoters in ruminants. These agents form lipid-soluble transport complexes with cations: K^+, Na^+, Ca^{2+}, and Mg^{2+}. Transport of these ions leads to disruption of cellular milieu, resulting in damage to the myocardium. Myocardial disease can lead to reduced cardiac function and congestive heart failure
 b. Toxicity occurs with overdosing as a result of mixing errors or exposure to a species for which the ionophore was not intended
 c. Clinical signs include lethargy, weakness, altered gait, recumbency, and sudden death. Tachycardia with normal or abnormal rhythm is often noted
 d. Diagnosis is supported by analysis of suspected feed for ionophore concentrations. Elevated skeletal muscle enzymes and cardiac isoenzymes of creatine kinase and lactate dehydrogenase are also supportive of diagnosis
 e. No specific treatment is available. General supportive care is indicated
 4. Plant cardiotoxicity
 a. Toxic compounds from plants that can affect cardiac function are most commonly alkaloid or glycoside compounds. Plants that contain alkaloids include yews (*Taxus* spp.), larkspurs, monkshood, and others. Cardiac glycoside-containing plants include milkweed (*Asclepias* spp.), azaleas (*Rhododendron* spp.), digitalis, oleander, and many others

b. Cardioactive alkaloids can exert a variety of affects on the myocardium
(1) Alkaloids can cause arrhythmias and tachycardia, reduce cardiac contractility, as well as induce a variety of systemic effects
(2) Clinical signs may include depression, gastroenteritis, diarrhea, dyspnea, bradycardia or tachycardia, and others
c. Cardiac glycosides inhibit adenosine triphosphatase (ATPase) activity of the sodium-potassium ATPase pump, which increases intracellular sodium and calcium. Results in positive inotropy and cardiac arrhythmias
(1) Clinical signs may include bradycardia or tachycardia, arrhythmias, and cardiac conduction abnormalities
(2) GI signs may include anorexia, abdominal pain, diarrhea, and ptyalism
(3) Convulsions and sudden death also occur
d. Plant poisoning often occurs when toxic plants are harvested with forages that are made into hay or when livestock graze toxic plants because of scarcity of other forages
e. Supportive care and administration of activated charcoal may help affected animals. Specific treatments may include antidysrhythmics for cardiac arrhythmias

IV. Respiratory diseases
A. Examination
1. Examination of the respiratory system should initially include observation of the animal from a distance to assess resting respiratory rate and effort. The animal should be observed for abnormal respiratory pattern, nasal discharge, coughing, respiratory stridor, and increased respiratory effort
2. Physical examination should include assessment of nasal passages and sinuses, oral cavity, retropharyngeal lymph nodes, larynx and trachea, and auscultation of the lung fields
3. The lung fields of small ruminants can be found between the 6th and 11th ribs. Both sides of the thorax should be ausculted as well as the trachea. Upper respiratory noise is typically louder in the trachea and thus may be distinguished from lower respiratory noise
4. Diagnostics: Further investigation into respiratory disease may include a complete blood count (CBC), thoracic radiographs and ultrasound, blood gas analysis, transtracheal wash, nasal swab, and other techniques, depending on availability and affordability

B. Upper respiratory diseases
1. Nasal neoplasms
a. Nasal tumors occur rarely in sheep and goats. Adenomas, adenocarcinomas, and adenopapillomas are most commonly described as occurring in sheep. Nasal adenocarcinomas also occur in goats. Nasal adenocarcinomas in sheep are believed to be associated with a retrovirus
b. Adenocarcinomas may be unilateral or bilateral and usually occur in yearling to adult sheep but can occur much earlier. Tumors originate from nasal mucosa and are generally benign but locally invasive
c. Neoplastic growths in the nasal passages result in decreased airflow, increasing stridor, dyspnea, exercise intolerance, sneezing, facial asymmetry, and exophthalmos
d. Diagnosis can be accomplished by endoscopy, radiography, and tissue biopsy
e. Surgical removal can be curative. Without intervention, most animals die within 90 days of onset of clinical signs
2. Sinusitis
a. Occurs most commonly secondary to dehorning or dental disease. Overzealous dehorning can lead to frontal sinus inflammation and infection within weeks or months. Tooth-root disease can lead to maxillary sinus disease
b. Clinical signs include nasal discharge, facial deformity and swelling, asymmetric airflow through the nares, and head pressing
c. Sinus drainage and lavage are often indicated in addition to broad-spectrum antibiotic therapy
3. Parasitic infestation
a. Larvae of *Oestrus ovis* flies can inhabit the nasal passages of sheep. Flies deposit their larvae in the nares, then larvae migrate through the nasal passages, dorsal turbinates, and sinuses. Within weeks or months, the larvae emerge to pupate
b. Sheep with "nasal bot" infestation are often asymptomatic, but migrating larvae can cause sinusitis or a secondary bacterial infection. Clinical signs include nasal discharge, sneezing, head-shaking, stridor, and reduced airflow. Aspiration pneumonia can be a sequela. Goats are usually not susceptible to *O. ovis* infestation
c. Endoscopy and radiographs can support diagnosis
d. Ivermectin (200 μg/kg orally or subcutaneously) is an effective treatment
4. Retropharyngeal abscesses
a. Enlarged retropharyngeal lymph nodes occur with *Corynebacterium pseudotuberculosis* infection. Identification of retropharyngeal abscesses should prompt further diagnostics and examination of other peripheral lymph nodes
b. Diagnosis can be confirmed by culture of a fine-needle aspirate sample. Lancing and lavaging of abscesses are generally not recommended because of risk of spreading the disease agent

C. Lower respiratory diseases
1. Bacterial pneumonia
a. The most common etiologic agent of bacterial pneumonia in sheep and goats is *Pasteurella haemolytica*, a gram-negative

coccobacilli. Both biotypes of *P. haemolytica*, A and T, cause pneumonia, but biotype A is more commonly isolated

b. *P. haemolytica* produces virulence factors, including lipopolysaccharide and endotoxin, that are important in the pathophysiology of pneumonic pasteurellosis. A number of factors can predispose sheep and goats to developing pasteurellosis, including environmental stresses, transport, and concurrent disease. Other infectious agents may also contribute to the development of pasteurellosis, including respiratory viruses (parainfluenza-3, respiratory syncytial virus, and adenovirus type 6) and other bacterial agents (*Mycoplasma ovipneumoniae*, *Chlamydia*, *Bordatella parapertussis*)

c. Clinical signs of pneumonia include fever, coughing, increased respiratory rate, and mucopurulent nasal discharge. Crackles and wheezes may be heard on auscultation of lung fields. Other systemic signs include depression, anorexia, and weight loss. Sudden death may be the only clinical sign in some cases. Otitis media, arthritis, and septicemia may occur in conjunction with pasteurellosis

d. Diagnosis is confirmed by isolation of *P. haemolytica* at necropsy. Typical lesions noted at necropsy include fibrinopurulent pleuropneumonia with pleural and peritoneal effusion. Lung consolidation and coagulative necrosis are also seen

e. Treatment with parental antibiotics oxytetracycline, sulfonamides, ampicillin, penicillin, and others is effective

f. Prevention can be achieved by minimizing stress and establishing vaccine programs

g. *Mycoplasma ovipneumoniae* and other *Mycoplasma* spp. also cause bacterial pneumonia in sheep, referred to as enzootic pneumonia, chronic nonprogressive pneumonia, and atypical pneumonia

2. Respiratory viruses

a. Viruses that contribute to respiratory disease in sheep and goats include parainfluenza type 3, adenoviruses, respiratory syncytial virus, ovine and caprine herpesviruses

b. Both sheep and goats are affected by closely related lentiviruses that cause pneumonia. Sheep are affected by the ovine lentivirus (OvLV), and goats are affected by the caprine arthritis-encephalitis virus (CAEV)

c. OvLV is a nononcogenic, single-stranded *Retroviridae* RNA virus that causes a chronic progressive pneumonia in sheep called ovine progressive pneumonia (OPP)

d. OPP has been reported worldwide. Virus infects monocytes, where it may evade the immune system, and replicates in macrophages. Lesions may be found in the lungs, mammary glands, synovium, and central nervous system (CNS). Pneumonia is the most common manifestation, but viral infection also causes mastitis ("hard bag"), arthritis, and encephalitis. Virus can be transmitted through milk and colostrum. Horizontal transmission via the respiratory route is also possible. Many sheep are asymptomatic carriers

e. Clinical signs of OPP may become more apparent after a stressful event and include progressive malaise and weight loss, leading to emaciation, lethargy, dyspnea, tachypnea, nasal discharge, and coughing

f. Presumptive diagnosis can be based on clinical signs and lack of response to treatment. Diagnosis can be supported by serologic results by AGID, enzyme-linked immunosorbent assay (ELISA), and indirect immunofluorescent test and can confirm diagnosis in cases with clinical signs

g. No effective treatment is available. Mortality is 100%

h. Management measures can be taken to help prevent spread of the virus. Operate a closed flock; identify and eliminate infected animals. Seropositive animals should be separated from the rest of the flock. Virus-free colostrum and milk should be fed to nursing lambs

i. CAEV is similar to the ovine lentivirus and causes chronic, multisystemic disease in goats

j. The most important route of transmission is from dam to kid via infected colostrum. Horizontal transmission can occur, but it is less efficient. The passive transmission of anti-CAEV antibodies in colostrum has not been found to be protective but instead helps confirm transmission of the virus

k. Pathogenesis of CAEV is similar to that of OvLV, producing lesions in the lungs, mammary glands, synovium and CNS. Both viruses may remain latent in an infected animal's monocytes

l. Clinical signs of CAE pneumonia are similar to those seen in sheep with OPP (i.e., insidious, progressive pneumonia with increasing weight loss and dyspnea)

m. Diagnosis of CAE is supported by serologic results in combination with presence of clinical signs. Serologic testing by ELISA and AGID are often used

n. No curative treatment is available. Once infected, a goat is infected for life and becomes a persistent carrier

o. Prevention measures are similar to those recommended for OPP. Emphasis should be placed on culling animals with clinical signs and preventing transmission to kids via infected colostrum. Pasteurized colostrum or colostrum from a negative herd should be fed to neonates

V. Urogenital diseases
 A. Evaluation of the urinary system should include observation of urination and palpation; examination of external urogenital structures, exteriorization of the penis, rectal palpation, and attaining a complete history of diet and reproductive history
 B. Urinalysis and ultrasonography of renal and urinary structures are valuable diagnostic techniques, as are serum biochemistry values
 C. Plant toxicities
 1. Many plants can affect the renal system of small ruminants. One of the common forms of nephrotoxicity in sheep and goats is due to ingestion of oxalates. Ingested oxalates combine with calcium to form insoluble calcium oxalate calculi in the urinary tract
 2. Animals may present with lethargy, anorexia, depression, tetany, pulmonary edema, and death
 3. Treatment consists of hydration, promotion of diuresis, and correction of electrolyte abnormalities. Oral magnesium hydroxide and activated charcoal may be indicated as well
 4. Oxalate-containing plants include pokeweed (*Phytolacca americana*), redroot pigweed (*Amaranthus retroflexus*), Russian thistle (*Salsola kali*), cultivated rhubarb (*Rheum rhaponticum*), sugar beet leaves (*Beta vulgaris*), curly dock (*Rumex cripsus*), and several others
 5. Oak (acorn) toxicity
 a. Consumption of acorns or oak leaves and all parts of *Quercus* spp. plants can result in renal tubular necrosis and renal failure in sheep and goats. Goats are found to be more resistant to oak toxicity than are sheep
 b. The toxic principle of *Quercus* spp. is gallotannic acid, which is converted to tannins and other toxic compounds in the rumen. Tannins bind to epithelial cells in the GI tract and renal tubules as well as vascular endothelium, resulting in GI ulceration, renal tubular necrosis, and loss of intravascular fluid, respectively
 c. Clinical signs include depression, anorexia, dehydration, polyuria, edema, abdominal pain and constipation followed by diarrhea, azotemia, metabolic acidosis, and electrolyte abnormalities
 d. Diagnosis can be based on history of acorn or oak consumption in conjunction with clinical signs and evidence of acute renal failure. GI ulceration and hemorrhagic enteritis can be seen at necropsy in addition to perirenal edema, hydrothorax, and hydroperitoneum. Histopathologic lesions include tubular necrosis, tubules devoid of epithelium, and dilated tubules
 e. Treatment is supportive and is aimed at addressing electrolyte abnormalities, correcting dehydration, and promoting diuresis. Animals that survive acute stages of toxicity and acute renal failure may develop chronic renal disease
 f. Provision of 10% calcium hydroxide in feed rations has been recommended to prevent the effects of oak toxicosis. Ensuring the availability of forage and maintaining good pastures free of toxic plants is a key factor in preventing toxicosis
 D. Enterotoxemia
 1. Type D strains of *Clostridium perfringens* produce epsilon toxin, which causes multisystemic disease by increasing vascular permeability. Postmortem lesions include hyperemia and edema in renal tissue ("pulpy kidney disease")
 2. Death may occur within 12 to 24 hours. Treatment is usually unsuccessful. Preventative measures include vaccination with bacterin toxoid
 E. Pyelonephritis
 1. Infection of the kidneys in sheep and goats has been documented to be caused by *Escherichia coli*, *Corynebacterium renale*, and *Chlamydia psittaci*. Pyelonephritis may be unilateral or bilateral
 2. Clinical signs include dysuria or anuria, anorexia, and weight loss. Urinalysis may indicate hematuria, proteinuria, and an elevated white blood cell (WBC) count
 3. Administration of procaine penicillin G or ceftiofur has been found to be effective treatment
 F. Urolithiasis
 1. Formation of urinary calculi or uroliths causes disease by obstruction of urine flow and trauma to the urinary tract. Commonly seen in intact and castrated male small ruminants
 2. Urinary calculi form as a result of dietary and management factors. Ruminants on grain-based, high-phosphorus diets tend to form triple phosphate calculi consisting of calcium, ammonium, and magnesium. Alkaline urine (pH greater than 8.5; range 7.0-9.5) promotes formation of these calculi. Acidic urine promotes formation of oxalate and xanthine calculi. Water deprivation also promotes formation of uroliths
 3. Early castration predisposes male small ruminants to obstructive urolithiasis. Decreased androgen levels prevent urethras from reaching full diameter, increasing the risk of urolith entrapment
 4. Uroliths can form in the kidneys, bladder, or urethras. Clinical signs of urolithiasis can vary depending on degree of obstruction and location of urolith formation. Uroliths are often entrapped in multiple sites. In male small ruminants, calculi are frequently found in various portions of the urethra: ischial arch, proximal flexure of the penis, and urethral orifice and urethral process
 5. Animals with partial obstructions may demonstrate signs of mild abdominal pain, stranguria,

dribbling urine, and hematuria. Owners often mistake stranguria for signs of straining to defecate. Sheep or goats with complete obstructions often present with signs of increasing abdominal pain, reduced appetite, frequent stranguria, bruxism, tail flagging, and vocalization. An enlarged bladder may be appreciated by abdominal palpation or ultrasonography. Rectal palpation may reveal a distended or pulsating urethra

6. Serum biochemistry analysis often reveals severe azotemia and elevated serum potassium as a result of postrenal obstruction. Urinalysis may reveal crystalluria, hematuria, and proteinuria
7. Treatment
 a. Medical or surgical treatment for restoration of urine flow can be pursued depending on the degree of obstruction and value of the animal
 (1) Medical treatment
 (a) Amputation of the urethral process
 (b) Retrograde flushing of urethra
 (c) Partial obstructions may be treated with urine acidifiers (i.e., ammonium chloride 300 mg/kg by mouth) in conjunction with NSAIDs to promote dissolution of uroliths and reduction of inflammation
 (2) Surgical treatment: Common surgical options include tube cystotomy, perineal urethrostomy, and bladder marsupialization
 b. The practitioner should be aware that delayed treatment of complete obstruction can result in rupture of the bladder and urine accumulation in the abdominal cavity ("water belly"). Even with proper treatment, urethral strictures can form, predisposing affected ruminants to recurrence of the disease. Treatment and management of this disease can therefore be frustrating and costly to the owner
8. Prevention
 a. Diet and water management
 (1) Maintaining calcium-to-phosphorus ratios of 2.5:1 is recommended to prevent calculi formation
 (2) Dietary protein levels should be adequate but not excessive to reduce urinary mucoprotein content and thus inhibit urolith development
 (3) Always provide access to fresh, palatable water
 (4) Addition of up to 4% salt may help increase water intake and thus dilute urine
 (5) Add urine acidifiers to feed (e.g., ammonium chloride, 7 to 10 g/day) to hinder calculi formation
 b. Management: Discourage owners from pursuing early castration for male ruminants

G. Reproductive diseases
 1. Breeding
 a. Bucks of most breeds reach sexual maturity at 4 to 5 months of age; however, pubertal age can vary with breed, ranging from as early as 2 to 3 months, up to 12 to 48 months. Pubertal age of does can also vary with breed but most commonly occurs between 6 and 8 months of age
 b. Rams reach sexual maturity around 5 to 6 months of age, depending on breed and season of birth. Pubertal age in ewes ranges from 7 to 8 months of age
 c. Sheep and goats are typically seasonal short-day breeders, being anestrus in the spring and early summer. Considerable variation can occur with breed and geographic location
 d. Gestation length for does and ewes is approximately 150 days
 e. Common reproductive problems encountered in sheep and goats are pregnancy toxemia, abortion, and vaginal prolapse
 2. Abortion
 a. Most common bacterial causes of abortion in sheep and goats include *Chlamydia psittaci*, *Toxoplasma gondii*, and *Campylobacter* spp.
 b. Viral causes of abortion include blue tongue virus, Akabane virus, border disease, and Q fever
 c. Other infectious causes include brucellosis, leptospirosis, and *Salmonella* spp.
 3. Vaginal prolapse
 a. Generally occurs in the last month of gestation in multiparous ewes
 b. Associated with obesity, persistent coughing, extreme tail docking, or increased abdominal filling caused by poor-quality forage diets
 c. Treatment may include administration of an epidural followed by manual replacement of vagina. Once replaced, the vagina may be retained with a plastic retainer, retention harness, or placement of sutures in pursestring or mattress patterns or a Buhner suture

VI. Neurologic diseases
 A. Small ruminants suspected of being affected by a neurologic disease should have a full physical examination as well as a neurologic examination. The neurologic examination should be conducted to reveal whether or not the animal is suffering from neurologic deficits and the neuroanatomic location of the lesion
 B. Examination should include evaluation of mentation, response to stimuli, posture, cranial nerves I-XII, gait, proprioception, and spinal reflexes
 C. Further diagnostics may include obtaining a complete history; complete WBC; serum biochemistry; skull, spinal, or limb radiography; and spinal fluid centesis
 D. Scrapie
 1. Reportable transmissible spongiform encephalopathy affecting sheep and goats, causing a chronic degenerative disease of the CNS.

The prion-associated disease is characterized by a long incubation period and an invariably fatal, progressive, debilitating neurologic disease

2. Clinical signs occur in animals 1 to 5 years of age. Clinical onset is slow and progressive. Behavioral changes and weight loss become apparent initially, followed by intense pruritus. The intense pruritus can lead to self-mutilation, wool loss, and secondary dermatitis. Tremors, ataxia, collapsing episodes, seizures, bruxism, and other signs occur later in the course of disease
3. Diagnosis is confirmed by postmortem immunohistochemical staining and microscopic examination of brain tissue
4. Sheep and goat producers can participate in a voluntary federal program designed to control scrapie called the Scrapie Flock Certification Program. Flocks are assessed over several years to achieve clearance to export and sell sheep nationally and internationally without restriction
5. Resistant flocks can be developed by selecting animals with resistant genotypes. Resistance is controlled by the prion protein gene. Resistant genotypes are $AA_{136}RR_{154}RR_{171}$ and susceptible genotypes are $VV_{136}RR_{154}QQ_{171}$

E. Listeriosis
1. Encephalitis in sheep and goats caused by gram-positive bacteria *Listeria monocytogenes*. Disease is most commonly associated with silage diets when the soil-dwelling organism is found in rotting vegetation, but it can affect animals on various diets. Transmission of disease can occur by ingestion of fecal-contaminated feeds
2. The bacteria gains access through oral mucosa and is thought to migrate along the trigeminal nerve to the brainstem, causing neuritis and encephalitis. Clinical signs can occur acutely and progress rapidly
3. Bacteria can survive for long periods in the environment. Once infected, an animal can shed the bacteria in milk, uterine fluid, feces, and eye secretions
4. A wide range of clinical signs includes depression and cranial nerve deficits such as a head tilt, circling, ataxia, ear or lip droop, inability to eat, loss of facial sensation or tongue tone, loss of jaw tone, and blindness
5. Diagnosis is based on clinical signs (including results of neurologic examination localizing lesions to the brainstem) and history. Analysis of cerebrospinal fluid (CSF), indicating elevated protein and mononuclear pleocytosis is supportive. Diagnosis is confirmed by fluorescent antibody test of brainstem tissue at necropsy. Microabscess formation and perivascular cuffing are seen in medulla-pons
6. Treatment must include high doses of penicillin, ampicillin, or oxytetracycline in addition to antiinflammatory agents. Supportive care is often necessary, particularly with sheep or goats that cannot eat or drink. Prognosis is guarded, as treatment is often unsuccessful
7. *L. monocytogenes* is a zoonotic and can cause several diseases in humans. Milk from affected animals must be pasteurized before consumption

F. PEM
1. PEM is a description of the lesion found in brain tissue following increased intracranial pressure and subsequent pressure necrosis, also known as *cerebrocortical necrosis*. PEM can be caused by metabolic derangement and toxic agents
 a. Thiamine deficiency
 (1) Thiamine is required for normal brain cell metabolism. Lack of thiamine can result in brain cell swelling and death from pressure necrosis. Thiamine deficiency can result from altered rumen function. Ruminants derive most of their daily thiamine requirement via rumen flora metabolism. Significant changes in rumen flora, as with grain overload or rumen acidosis, can lead to a cessation of adequate thiamine production and secondary thiamine deficiency
 (2) Ingestion of thiaminases: Bracken fern (*Pteridium aquilinum*) contains thiaminase and ingestion can lead to thiamine deficiency and clinical signs of PEM
 (3) Amprolium toxicity: The coccidiostat amprolium is a thiamine analog. Overdosing can lead to an effective thiamine deficiency by competitive inhibition
 b. Salt toxicity-water deprivation
 (1) Hypernatremia can occur by either overconsumption of salt or deprivation of water
 (2) Results in accumulation of salt and hyperosmolar substances in cerebral tissue. Subsequent ingestion of water leads to fluid accumulation in cerebral tissue, resulting in swelling and pressure necrosis
 c. Lead toxicity
 (1) Lead intoxication interferes with normal cerebral tissue metabolism
 (2) Results are similar to other forms of PEM with cellular swelling and pressure necrosis
 d. High sulfur diet
 (1) Ingested sulfur compounds are metabolized to toxic sulfide ion
 (2) Some cases of PEM have been linked to elevated levels of sulfur compounds found in feed or water
2. Clinical signs can develop acutely and may vary but are related to cerebral lesions. Frequently observed signs are changes in behavior, wandering, central blindness with intact papillary light response, nystagmus,

ataxia, seizures, opisthotonus, recumbency, coma, and death
3. Diagnosis is based on history and clinical signs. PEM cases are often responsive to thiamine supplementation; therefore, response to treatment also supports diagnosis. Ruling out other differentials by serum chemistry, CBC, and CSF tap can also support diagnosis. Diagnosis is confirmed by finding characteristic lesions at necropsy, including autofluorescence of necrotic tissue under ultraviolet light
4. Treatment
 a. Aggressive therapy with parental thiamine (10 mg/kg IV every 4 hours for several days)
 b. Antiinflammatory therapy such as dexamethasone or NSAIDs
 c. Supportive care may be necessary for severely affected animals. Transfaunation is often indicated to restore rumen flora and rumen thiamine production
 d. Early recognition and treatment improve prognosis

G. Parasitic nematodiasis
1. *Parelaphostrongylus tenuis* (meningeal worm) is an internal parasite of white-tailed deer and is endemic in North America. The life cycle of the parasite in the deer is completed in 90 days. The worm migrates to the spinal cord of the deer and goes into the dura mater of the brain, but it does not normally cause signs of disease in the deer. Intermediate hosts are snails and slugs, which when ingested by other ruminant species, release larvae, which migrate to the spinal cord and cause damage to the CNS
2. The resultant neurologic deficits manifest as hind-end weakness, ataxia, reluctance to stand, circling, or abnormal head position. Affected animals are often still bright, alert, and responsive
3. Presumptive diagnosis is based on clinical signs. Eosinophilic pleocytosis in cerebral spinal fluid is strong support for diagnosis
4. Treatment involves supportive care for some cases including physical therapy and sling support for valuable animals. Medical therapy includes anthelmintics and antiinflammatory medications
5. Preventative measures include the following:
 a. Fencing stock away from grazing areas of white-tailed deer
 b. Reducing brush and freestanding water to reduce contact with intermediate hosts (snails and slugs)
 c. Intermittent dosing with ivermectin to kill migrating larvae (at 21- to 28-day intervals)

H. Clostridial diseases
1. Botulism
 a. *Clostridium botulinum* produces a neurotoxin that binds to the neuromuscular junction, competitively inhibiting the neurotransmitter acetylcholine. Flaccid paralysis results
 b. In ruminants, the most common botulism intoxication occurs by ingestion of the preformed toxin, often by ingesting rotten vegetation or carcasses in forage
 c. Clinical signs occur within a week of ingesting the toxin. Animals present with signs of generalized muscle weakness. Loss of tongue tone is a common sign, along with dysphagia, bloat, regurgitation, and reduced rumen motility
2. Tetanus
 a. *Clostridium tetani* produces three toxins. Tetanospasmin is a potent toxin that prevents release of the inhibitory neurotransmitter glycine in the CNS, producing spastic paralysis
 b. *C. tetani* proliferates and produces toxins in wounds. Ruminants are often infected through contaminated wounds following tail docking or castration
 c. Early clinical signs include a stiff gait and difficulty on rising. Other signs include an elevated tail head ("pump-handle tail"), erect ears, a "sardonic grin," reduced rumen activity, and hypersensitivity to sound. Mild bloat often occurs initially. Clinical signs progress until the animal is recumbent and death occurs from respiratory paralysis
 d. Treatment involves cleaning and debriding castration or tail docking sites to eliminate the bacteria. High doses of penicillin and daily tetanus antitoxin doses are recommended. Tetanus antitoxin can be injected locally to prevent further absorption of toxin. Muscle relaxants such as acepromazine can be given to relieve clinical signs of muscle spasticity
 e. Infection with tetanus can be effectively prevented with an appropriate tetanus toxoid vaccination program
3. *Clostridium perfringens*
 a. *C. perfringens* is a commensal of the ruminant GI tract and a ubiquitous bacteria that produces enterotoxin types C and D
 b. Proliferation of the bacteria in the GI tract leads to production of enterotoxins that can act as neurotransmitters. The enterotoxins cause neurologic signs such as convulsions, opisthotonus, blindness, head-pressing, and sudden death
 c. Treatment is usually not successful, and mortality is nearly 100%

I. Lentiviruses
1. OvLV and CAEV can both cause neurologic disease in sheep and goats, respectively
2. OvLV rarely causes neurologic disease in adult sheep. Signs of ovine lentiviral leukoencephalomyelitis include ascending paralysis, weight loss, and rear-limb ataxia. Cranial nerve signs are observed occasionally. Signs progress to paralysis and death
3. CAEV causes leukoencephalomyelitis in kids 1 to 6 months old. Clinical signs include unilateral or bilateral hindlimb paresis and ataxia with a short, choppy gait. Cranial nerve signs

include a head tilt and circling. While the kids remain bright, alert, and continue to nurse, signs progress over several weeks and are irreversible. No treatment is available

Supplemental Reading

Ballweber LR, editor. *Veterinary Clinics of North America Food Animal Practice: Ruminant Parasitology.* Philadelphia, 2006, Saunders.

Callan, RJ, Van Metre DC. Viral diseases of the ruminant nervous system. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3):326–362, 2006.

Cebra, CK, Cebra ML. Altered mentation caused by polioencephalomalacia, Hypernatremia, and lead poisoning. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3):287–302, 2006.

Constable PD, editor. *Veterinary Clinics of North America Food Animal Practice: Ruminant Neurologic Diseases.* Philadelphia, 2004, Saunders.

Divers, TJ. Acquired spinal cord and peripheral nerve disease. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3):231–242, 2006.

Gupta RC, editor. *Veterinary Toxicology: Basic and Clinical Principles.* New York, 2007, Academic Press.

Howard JL, editor. *Current Veterinary Therapy: Food Animal Practice,* 3 rd ed. Philadelphia, 1993, Saunders.

Howard JL, Smith RA, editors. *Current Veterinary Therapy: Food Animal Practice.* Philadelphia, 1999, Saunders.

Jolley, WR, Bardsley KD. Ruminant coccidiosis. *Vet Clin of North Am Food Anim Pract Rumin Parasitol* 22(3): 613–622, 2006.

Morin, DE. Brainstem and cranial nerve abnormalities: Listeriosis, otitis media/interma, and pituitary abscess syndrome. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3):243–274, 2006.

Nagy, DW. Praelaphostrongylus tenuis and other parasitic diseases of the ruminant nervous system. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3): 393–412, 2006.

Pugh DG, editor. *Sheep and Goat Medicine.* Philadelphia, 2002, Saunders.

Rings, MD. Clostridial disease associated with neurologic signs. Tatanus, botulism, and enterotoxemia. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3); 379–392, 2006.

Smith BP. *Large Animal Internal Medicine,* 4th ed. St Louis, 2009, Mosby.

Tyler, JW, Middleton JR. Transmissible spongiform encephalopathies in ruminants. *Vet Clin North Am Food Anim Pract Rumin Parasitol* 22(3):303–326, 2006.

Youngquist RS, Threlfall WR, editors. *Current Therapy in Large Animal Theriogenology*. Philadelphia, 2007, Saunders.

Zajac, AM. Gastrointesinal parasites of small ruminants: Life cycle, anthelmintics and diagnosis. *Vet Clin North Am Food Anim Pract Rumin Parasasitol* 22(3):529–242, 2006.

Swine Medicine and Management

52 CHAPTER

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HERD MANAGEMENT

I. Estrous cycle
 A. Pubertal estrus occurs at about 6 months of age and about 100 to 120 kg in gilts
 B. Gilt age at pubertal estrus can be reduced by exposure to a boar. To be effective, the gilts should be at least 165 days of age, and the boar must be at least 9 months old
 C. Gilts and sows are polyestrous with a cycle duration of 21 days (range 18 to 24 days)
 D. The estrous cycle consists of diestrus (luteal phase of about 15 days), proestrus (follicular phase of about 4 days), and estrus (sexual receptive period of about 2 days)
 E. The luteinizing hormone (LH) surge controlling time of ovulation occurs at the onset of estrus
 F. Ovulation occurs about 40 hours after onset of the LH surge (about 70% of the way through estrus). The process of ovulation takes 2 to 4 hours
 G. The follicular remnants luteinize to form corpora lutea that secrete progesterone. The corpora lutea are required for maintenance of pregnancy; loss of the corpora lutea at any time will terminate the pregnancy
 H. If the animal is not pregnant, the luteolytic signal (prostaglandin F2α) is secreted from the endometrium during days 12 to 14 of the estrous cycle. The PGF2α enters the uterine vein, moves to the ovarian artery by countercurrent transfer, arrives at the ovary, and induces luteolysis
 I. Estrous periods can be synchronized by feeding 15 to 20 mg/day of the progestagen allyl trenbolone
 J. Estrus occurs about 5 days after last feeding. If amount fed is less than 13 mg/day, cystic follicles may occur

II. Breeding
 A. Most common breeding method is artificial insemination (AI), although pasture breeding is used on many outdoor farms
 B. Boars ejaculate about 75×10^9 sperm in 250 mL seminal plasma. AI doses contain only $2\text{-}4 \times 10^9$ sperm in 80 to 100 mL of extender. Semen is deposited into the cervix of the sow
 C. For optimal fertility, AI should occur during the 24 hours before ovulation. To maximize the likelihood of this, AI is performed at 24-hour intervals while the sow is in estrus
 D. Sperm are transported to the oviduct by coordinated uterine contractions, where a sperm reservoir is formed in the first 2 to 4 cm of the isthmus
 E. To ensure adequate uterine contractility and good fertility, a boar should be in front of the sow during insemination
 F. Toward the end of the estrous period (after ovulation), uterine immunocompetence is reduced because of a shift from estrogen to progesterone dominance. Insemination at the end of the estrous period or early diestrus is a major cause of uterine infections

III. Pregnancy
 A. Duration of gestation averages 115 days, normally distributed with a range of 111 to 119 days
 B. The signals for maternal recognition of pregnancy are embryonic estrogen secretion. The first signal occurs at about 11 to 12 days after breeding; the second signal is more prolonged and occurs during days 17 to 30 after breeding
 C. The effect of the embryonic estrogen is to redirect the luteolytic PGF2α away from the uterine blood supply and into the uterine lumen. The signal also induces production of luteotrophic PGE2
 D. To ensure an adequate signal for maternal recognition of pregnancy, there must be at least four embryos in the uterus
 E. If bred sows fail to conceive or conceive but have too few embryos to provide an adequate first signal, they exhibit a regular (18 to 24 or 38 to 45 days) return to estrus. Regular returns are considered a failure of conception. If the ratio of 21- to 42-day returns is less than 3:1, a problem with estrus detection is likely
 F. If sows conceive and receive the first signal, but not the second signal, for maternal recognition of pregnancy, there is a partial luteotrophic effect and the sows exhibit an irregular (25- to 37-day) return to estrus. Irregular returns are considered a failure of pregnancy. If regular to irregular return ratio is less 3:1, too many pregnancies are being lost
 G. If a sow receives both signals for maternal recognition of pregnancy and then loses her litter, she may become pseudopregnant

IV. Parturition (farrowing)
 A. Farrowing is induced by intramuscular injection of PGF2α (or analog) up to 2 days before the due date

B. Most sows farrow within 36 hours of induction. A better response is obtained by "split-dose" injection into the vulva (i.e., injection of a half-dose in the morning and half-dose in the afternoon
C. Piglets are delivered about every 15-20 minutes. If the delivery interval approaches 40 minutes, manual extraction of piglets is likely necessary
D. Total duration of farrowing is 1 to 4 hours. If it approaches 5 hours, intervention is indicated
E. Prolonged farrowings are associated with increased incidence of stillbirths
F. Injection of oxytocin 24 h after injection of PGF2α is done to speed up parturition. However, oxytocin causes excessively strong uterine contractions, umbilical trauma, and increased stillbirths. Routine use of oxytocin is contraindicated

V. Lactation
A. The most common lactation length is about 21 days. Shorter lactations (12-16 days) may reduce post-weaning fertility
B. If sows do not consume sufficient nutrients during lactation, post-weaning fertility is reduced (longer wean-estrus intervals, reduced pregnancy rates, and smaller subsequent litters)
C. The primary objective in lactation management is maximizing sow feed intake. High ambient temperatures, such as in the summer, reduce sow feed intake and can result in seasonal infertility
D. The first limiting amino acid for swine is lysine. Lactating sows require about 60 g of total lysine per day, and if lactation feed intake is significantly reduced, dietary fortification with lysine is indicated

VI. Wean-to-estrus interval (WEI)
A. Usually, sows exhibit estrus 4 to 5 days after weaning. A WEI of 6 to 12 days is associated with reduced subsequent farrowing rates and litter sizes. A longer WEI is associated with parity 1 sows, short lactations, and low lactation feed intakes
B. Long WEI can be treated with an injection of gonadotrophins at weaning
C. Short WEI (<6 days) results in a longer duration of estrus and, in contrast, a long WEI (>5 days) results in a short duration of estrus
D. Because sows ovulate about 70% of the way through estrus, this means the interval from estrus onset to ovulation is longer in sows having a short WEI than in those having a long WEI. Timing of AI should be modified accordingly

GASTROINTESTINAL DISEASES

Enteric Bacteria

I. Colibacillosis
A. Colibacillosis, caused by the gram-negative flagellated bacillus *Escherichia coli* (e.g., F4 [K88], F5 [K99]), induces a watery diarrhea at any age, including the first few weeks after weaning. Occasional septicemia may occur during the first 48 hours of life. Edema disease is a unique form of colibacillosis presenting with neurologic signs (see Edema Disease under Neurologic Disease)
B. The pilus (fimbria) mediates adhesion to enterocytes or the overlying mucus. The most common pilus types in neonates are K88, K99, F41, and 987P. Post-weaning, the most common pilus types are K88 and F18
C. Following adhesion, *E. coli* elaborate enterotoxins that affect ion channels and cause active secretion of chloride, which is followed passively by water. The secretory diarrhea leads to death from dehydration
D. Diagnose colibacillosis on diarrhea with absence of blood, mild or no villus atrophy, and isolation of profuse or pure culture of pathogenic serotype
E. Treat affected suckling pigs with antimicrobial (e.g., gentomycin). If not currently performed, institute sow vaccination against *E. coli*, and improve farrowing house hygiene. Additional control measures for weaned pigs include 2500 to 3000 ppm zinc oxide in the diet for the first 2 weeks after weaning and, if necessary, antimicrobials in the water supply

II. Clostridial disease
A. Clostridia most commonly affecting pigs are *C. perfringens* types A and C and also *C. difficile*
B. Peracute or acute *C. perfringens* type C affects pigs within hours of birth. The less severe subacute or chronic forms affect pigs from 3 to 21 days
C. The bacterium elaborates β-toxin, causing enterocyte damage followed by bacterial penetration and adherence to the basement membrane
D. In the acute form, the toxin causes severe necrotizing-hemorrhagic enteritis, possibly with gas bubbles evident in the serosa. The pig often dies before any hemorrhagic diarrhea becomes evident
E. In the subacute-chronic form, diffuse fibrinous mucosal necrosis is observed without hemorrhage. The lesion is similar to that observed with coccidiosis
F. Diagnose on evidence of hemorrhagic enteritis in neonatal pigs with variable morbidity but high case mortality. On postmortem, the jejunum will appear bright purplish red
G. Definitive diagnosis requires demonstration of the β-toxin
H. Affected pigs will die, but others in the litter will be protected by oral ampicillin. Long-term control involves improved farrowing house hygiene and sow vaccination
I. *C. perfringen* type A is less severe, causing nonhemorrhagic diarrhea, usually in pigs less than 3 days old, but it can also occur in weaned pigs. It is characterized by a high morbidity but low mortality
I. Treat with oral penicillin or ampicillin, improved hygiene, and sow vaccination
J. *C. difficile* causes nonhemorrhagic diarrhea, usually in pigs 1 to 7 days of age with a high morbidity and relatively high (50%) case mortality. May also observe dyspnea

K. At postmortem, may observe gross lesions of mesocolonic edema, hydrothorax (hence dyspnea), or ascites
L. Diagnosis is based on clinical signs, postmortem lesions, and bacterial culture

III. Porcine proliferative enteropathy (PPE)
A. PPE is caused by the intracellular bacterium *Lawsonia intracellularis*. Fecal-oral infection leads to invasion of intestinal crypt cells, particularly in the ileum
B. Cellular infection leads to apoptosis, hyperplasia, and the crypts filling with polymorphonuclear neutrophils
C. Villus apical capillaries may dilate and rupture. Changes may regress, continue and result in benign adenomatosis, or they may become necrotic or potentially hemorrhagic
D. Usually, infection results in a soft stool (oatmeal consistency) seen in grow-finish. However, the hemorrhagic condition is more likely in young adults (e.g., replacement breeding stock)
E. In grow-finish, small intestine (particularly ileum and possibly proximal spiral colon) is thickened and reticulated (looks like the surface of the brain)
F. Diagnose on pig age, clinical signs, histology, polymerase chain reaction (PCR), or serology
G. Treat clinically affected pigs by injection of long-acting tetracyclines. To treat the group, effective antimicrobials can be "pulsed" (2 weeks in feed or 4 days in water). For control, pulse antimicrobials for 2 weeks (feed) or 4 days (water); then re-treat after 18 days. Objective is to allow infection and development of immunity without development of clinical disease
H. An effective vaccine is available

IV. Swine dysentery
A. The etiologic agent is *Brachyspira (serpulina) hyodysentariae*. Fecal-oral route of infection of the spirochaete leads to colonization and invasion of colon crypts, then of goblet and epithelial cells. Can affect any age of pig but peaks in 6- to 12-week-old pigs
B. The inflammatory response is associated with tissue loss, mast cell degranulation, and failure to reabsorb Na and Cl, causing a mucohemorrhagic diarrhea. Shedding of organisms in mucus protects them during passage to the colon of newly infected animals
C. Appetite may be normal
D. Diagnose on clinical signs and confirmed by bacterial isolation. Need to differentiate from severe whip worm infection
E. Treat individual pigs by injection or groups with in-feed or in-water tiamulin, valnemulin, or lincomycin

V. *Salmonella* spp.
A. The enterocolitis form of salmonellosis is usually the result of infection with *Salmonella typhimurium*, whereas infection with the host-adapted *Salmonella cholerasuis* is more likely to become septicemic. Can infect any age but tends to involve pigs from weaning to 80 kg
B. Initial signs of *S. typhimurium* infection include moderate anorexia, fever, and diarrhea. With time, may see mucus, fibrin, and blood in feces, although hemorrhagic diarrhea is not a prominent feature. Morbidity can be high and mortality moderate
C. At postmortem, colon and lower small intestine are edematous and ileocolic and mesenteric lymph nodes usually enlarged and edematous. Evidence of mucosal necrosis and, chronically, raised circular colonic lesions (button ulcers)
D. Infection with *S. cholerasuis* results in inappetence, depression, weakness, and cyanosis of extremeties. Diarrhea may occur after a few days. Morbidity is usually low or moderate, but case mortality is high
E. At postmortem, will see enlargement of spleen and possibly liver. Liver may have small, white to yellow foci of necrosis (paratyphoid nodules). If it localizes in the lungs, will see pulmonary congestion and edema
F. Diagnose salmonellosis on clinical and postmortem signs. Confirm with bacterial culture
G. Effective control requires good hygiene and pig comfort (low stress); vaccines are available. Antimicrobial therapy is effective, but a sensitivity screen should be done

Enteric Parasites

I. Coccidia
A. *Isospora suis* infection due to ingestion of sporulated oocysts in feces, food, or the environment. The oocysts give rise to sporozoites that infect epithelial cells in cranial third of jejunum
B. Diarrhea is often pasty to watery and yellow, occurring usually from about 7 to 10 days of age. Lesions are limited to the jejunum and ileum, which appear thickened with a necrotic lining and with villus atrophy (cf. chronic *C. perfringens* type C)
C. Morbidity is high, but mortality is usually less than 20%. Diagnose on diarrhea nonresponsive to antimicrobials and demonstration of organism
D. Where licensed, treat pigs with toltrazuril (Baycox) at 3 days of age to prevent disease

II. Worms
A. Roundworm (*Ascaris suum*) infections cause few clinical sign. Food conversion and growth rate may be reduced by 5% to 10%. Larvae migrate via the enteric mucosa through the liver and into the lungs. A moist cough may be detected during the migration phase. The greatest problem is condemnation of plucks at slaughter resulting from "milk spot" livers
B. Whipworms (*Trichuris suis*) penetrate the mucosa of the colon, resulting in a diffuse mucohemorrhagic typhlocolitis. Few clinical signs are observed unless the disease is complicated by secondary invaders, such as *Salmonella*

Enteric Viruses

I. Rotavirus
 A. Rotaviruses are a ubiquitous group of viruses causing diarrhea in animals from 3 days to 5 weeks of age but most commonly 10 to 21 days old
 B. Virus infects mature enterocytes, causing mild-moderate villus atrophy. Severe diarrhea is usually the result of bacterial superinfection
 C. Morbidity is nearly 100%, but mortality usually less than 10%
 D. Control requires better hygiene and improvement of sow's immune status before farrowing

II. Coronavirus
 A. Transmissible gastroenteritis (TGE) affects pigs of all ages and is caused by a coronavirus infecting mature enterocytes. Infection results in severe villus atrophy, leading to hypoglycemia, osmotic diarrhea, and death from dehydration. Also characterized by vomiting in young pigs and sows going off feed for 2 to 3 days
 B. In piglets, mortality is 100% (age 0 to 7 days), 50% (age 8 to 14 days), and 25% (age 15 to 21 days); mortality is rare after this age (older pigs are faster at enteric repair)
 C. Diagnose on epizootiology and clinical signs, confirmed by serology. Primary differential is porcine epidemic diarrhea (PED)
 D. There is no treatment for TGE. Control involves feedback of virus-rich intestinal contents from young pigs to establish a comprehensive herd immunity
 E. PED is also caused by a coronavirus with similar pathogenesis to TGE
 F. Type I PED resembles TGE except the explosive diarrhea as seen with TGE is seen only in weaned pigs (or older). Type II PED affects all pigs (including nursing pigs), but mortality in nursing pigs is much lower than that seen with TGE
 G. Vomiting and wasting disease of neonatal pigs (5 to 21 days) is caused by the coronavirus haemagglutinating encephalomyelitis virus
 H. In the vomiting and wasting syndrome, pigs display vomiting, depression, anorexia, and constipation. Pigs die in 36 to 48 hours or become progressively emaciated
 I. In the encephalomyelitis syndrome, initial signs are as above. Then any of a variety of signs will occur, including stilted gait, muscle tremors, nystagmus, blindness, convulsions, and paresis
 J. Diagnose on clinical signs, pig age, and serology. There is no treatment, but the herd will develop immunity and clinical signs will disappear

RESPIRATORY DISEASES

Bacterial

I. Mycoplasma (enzootic) pneumonia
 A. *Mycoplasma hyopneumoniae* infection is by aerosol, and it colonizes and subsequently destroys the airway cilia
 B. Destruction of the mucociliary apparatus compromises lung clearance, leading to pooling of infective material in the cranial-ventral lung lobes
 C. Infection usually occurs after 3 weeks of age, resulting in a dry barking cough and slowly spreading to most members of the group over a 3- to 14-week period
 D. Diagnosis is based on clinical signs, distinctive lung lesion (anterior-ventral plum-colored lesion), confirmed by serology or PCR
 E. Treat severely sick pigs with tiamulin. Treat the group with in-feed or water medications (e.g., tetracyclines, tiamulin, valnemulin)
 F. To control the disease, ensure all-in, all-out pig flows. Effective vaccines are available and should be administered at 3 and 5 weeks of age. Single-shot vaccines are now available

II. Pleuropneumonia
 A. Caused by infection with *Actinobacillus pleuropneumoniae* via direct contact or aerosol
 B. Lesions are largely the result of toxin production (APX I and III), which can be evident within 3 hours of experimental infection
 C. Acute disease in naïve pigs results in fever, dyspnea, blood-stained froth at the mouth (15% to 30% of cases), and 30% to 50% mortality within 36 hours of onset of clinical signs
 D. In subacute form, pigs are anorexic and have dyspnea and a cough
 E. Fibrinous exudates on pleural surface over pneumonic areas are evident by 12 to 24 hours, and necrohemorrhagic lesions are evident by 48 hours. Lesions are often most marked in the dorsocaudal (diaphragmatic) lobe
 F. Diagnose based on evidence of acute fatal respiratory disease with fibrous pleurisy and firm lung infarcts. Confirmed by serology, although bacterial culture is needed to differentiate from *A. suis*
 G. Treat clinically affected pigs by injection of effective antimicrobial (e.g., penicillin or ceftiofur). Treat the group by in-feed or water medication
 H. Control disease by all-in, all-out pig flow or segregated early weaning (less than 3 weeks). Vaccine is available

III. Atrophic rhinitis
 A. Caused by toxigenic *Pasteurella multocida* (usually capsule type D). Colonization of the nasal mucosa is facilitated by inflammation (e.g., associated with coinfection with *Bordatella brochiseptica*)
 B. Infection causes sneezing in pigs 1 to 8 weeks of age (may be paroxysmal with epistaxis) and mucopurulent nasal discharge
 C. *P. multocida* elaborates a dermonecrotoxin, causes death of osteoblasts, and upregulation of osteoclast activity. The net effect is irreversible nasal turbinate atrophy, distortion of the nasal septum, and possible shortening and twisting of upper jaw
 D. Diagnose on the basis of clinical signs confirmed by culture of nasal swab for toxigenic *P. multocida*
 E. Control is via medication (e.g., parenteral or oral trimethoprim [TMP]-sulfa, or ampicillin) at 3, 10, and 21 days of age followed by in-feed or in-water

medication after weaning. Prefarrowing sow vaccination, vaccinate piglets at 7 and 21 days, or both

Viral

I. Swine influenza virus (SIV)
 A. Most common subtype in swine is H1N1, although H3N2 is becoming more common. Other minor subtypes may also occur
 B. Virus enters the respiratory tract in aerosols and multiplies rapidly in bronchial epithelial cells, resulting in cellular necrosis. Virus may also infect alveolar septae. Inflammatory exudates block small bronchi, and alveolar necrosis occurs, as does bronchial hyperplasia
 C. In a typical outbreak, there is a sudden onset of respiratory illness involving almost all pigs. Animals become apathetic, prostrate, and anorexic, and they have fever. Coughing, sneezing, and dyspnea are common. Recovery is rapid, beginning about 7 days after onset of clinical signs. Mortality is usually low (i.e., less than 1%)
 D. Disease control involves vaccination and antimicrobials to control secondary infections

II. Porcine reproductive and respiratory syndrome (PRRS)
 A. Infection with PRRS can be via direct contact, aerosols, semen, and insects
 B. Virus multiplies in and may destroy alveolar macrophages and endothelium, causing vasculitis
 C. Respiratory signs are usually observed in weaned pigs, which show tachypnea and "thumping" respiration. The lesion is a moderate to severe interstitial pneumonia
 D. Diagnose on clinical signs and gross pathology confirmed by serology and virus isolation from lung and tonsils
 E. Disease control requires comprehensive sow immunity to prevent shedding virus. A vaccine is available, and partial depopulation (e.g., only the nursery phase of production) has been used successfully in disease eradication

III. Porcine circovirus associated disease
 A. This virus is associated with various diseases, such as post-weaning multisystemic wasting syndrome and porcine dermatitis and nephropathy syndrome
 B. Usually observed in weaned pigs (5 to 8 weeks old); may observe dyspnea associated with a moderate to severe interstitial pneumonia. Additionally, may see icterus, wasting, and an increase in mummies and stillbirths associated with fetal myocarditis
 C. Diagnosis is based on clinical signs confirmed by demonstration of inclusion bodies in lymphoid tissue (i.e. ileal Peyer's patches)
 D. Disease control involves ensuring that all piglets receive adequate colostrums, limiting cross-fostering and minimizing stress on the piglets. Vaccines are now available

NEUROLOGIC AND LOCOMOTOR DISEASE

I. Edema disease
 A. Caused by enteric verotoxin-producing *E. coli* (e.g., F18). The toxin causes arterial degeneration and increased vascular permeability
 B. Angiopathy results in focal malacia in the brainstem and edema in various locations, particularly the greater curvature of the stomach and eyelids
 C. Onset is characterized by death of a few of the fastest growing pigs about 10 to 14 days after placement in the nursery. Will also see evidence of neurologic involvement, such as ataxia and recumbency with paddling. If caught, pigs emit an unusual squeal because of laryngeal edema
 D. Morbidity is usually low, but mortality of affected pigs is high. There is no generally accepted control measure. However, during an outbreak, water acidifiers and antimicrobials may be of benefit

II. Streptococcal disease
 A. Pigs can become infected with *Streptococcus suis* during birth or very shortly thereafter. *S. suis* is transmitted between piglets by direct contact, ingestion, inhalation, or trauma
 B. Disease is usually seen in suckling pigs or in nursery pigs. The organism localizes in tonsilar crypts and then invades via lymphatics and may become stystemic
 C. Some organisms may survive in phagocytes and eventually localize in meninges, lungs, and joints. Clinical signs include ataxia, convulsions, opisthotonus, and death. If joints are involved, will observe polyarthritis
 D. Treat affected pigs with parenteral antimicrobials (e.g., penicillin or ceftiofur). Vaccines are available but are not always effective

III. Glasser's disease
 A. Infection of young pigs with *Haemophilus parasuis* can result in the same clinical signs as with *S. suis*
 B. Additionally, polyserositis is likely to be more marked; on postmortem the viscera of severely affected pigs may be "stuck together"
 C. In addition to disease in young pigs, Glasser disease is often observed where high-health young adult breeding stock are introduced to a conventional-health farm
 D. Treatment is the same as for *S. suis*
 E. Primary differentials in addition to *S. suis* are *Mycoplasma hyorhinis* (affects pigs aged 3 to 10 weeks, no fever, low mortality) and *M. hyosynoviae* (more than 10 weeks old, no fever, only arthritis)

IV. Salt poisoning
 A. Following a period of 2 or more days of water deprivation, the dehydration-associated increase in blood Na concentration leads to an increase in brain Na concentration
 B. If then allowed unrestricted access to water, blood Na concentration is reduced and the high brain Na content causes water to enter the brain, causing brain edema

SKIN DISEASE

I. Erysipelas
 A. Caused by infection with *Erysipelothrix rhusiopathiae*, which is a soil-borne organism that can be isolated from the tonsils of normal pigs. The organisms probably enter via the tonsils or the enteric lymphoid tissue, and a bacteremia follows
 B. Acute disease outbreaks are characterized by a few deaths in near-market pigs, with others being ill with high fevers. Following the acute phase, a few pigs may have discrete raised red-to-purple diamond-shaped areas of skin
 C. Affected pigs may also show resistance to standing because of very painful joints, and they develop vegetative valvular endocarditis. Pregnant sows may abort
 D. Disease usually responds rapidly to penicillin. Vaccines are available

II. Exudative epidermitis
 A. An acute nonpruritic exudative dermatitis in pigs from a few days to 6 weeks of age caused by infection with *Staphylococcus hyicus*, which produces an exfoliative toxin
 B. Organisms gain entry to the skin usually via trauma, such as can be caused in fighting between piglets
 C. Suppurative folliculitis and excessive sebaceous gland secretion lead to a greasy exude over the lesions, followed by severe epidermal erosion and ulceration and drying and cracking of the exudates. Lesions enlarge and coalesce to cover large areas of the body
 D. Death is due to dehydration and loss of electrolytes and serum proteins
 E. Caught early, the disease may respond to antimicrobials and spraying with antiseptic solutions
 F. Disease control usually involves clipping the teeth of baby pigs to reduce risks of skin trauma. Provision of a cleaner, dryer environment with reduced humidity may also be of benefit

III. Swine pox
 A. Caused by pox virus, a mild disease resulting in 1- to 3-mm round-to-oval red skin spots, especially on the belly, axillae, and face
 B. Lesions mature and brown-to-black crusts form. These heal uneventfully
 C. Control relies on herd immunity and control of vectors such as hog lice by application of insecticide

IV. Mange
 A. An intensely pruritic condition caused by infestation with the mange mite, *Sarcoptes scabiei*, which spreads among pigs by direct contact
 B. With chronicity, skin becomes thickened and wrinkled and pigs have a reduced growth rate
 C. Diagnose on evidence of intense pruritis and demonstration of the mite in skin scrapings
 D. Herd eradication of the mange mite can be done by treatment of all pigs with avermectins (e.g., ivomectin)

V. Ringworm
 A. Caused by fungi, usually *Trichophyton mentagrophytes*, *T. verrucosum*, or *Microsporum nanum*, and may affect any age of pig, but especially sows
 B. In younger pigs, it must be differentiated from pityriasis rosea
 C. Ringworm is usually self limiting but may take months to heal completely
 D. Should be considered contagious to humans

REPRODUCTIVE DISEASES

I. Porcine parvovirus (PPV)
 A. Most farms are infected with PPV, and oronasal transmission occurs among pigs of all ages
 B. Infection is clinically inapparent except in developing fetuses. Transplacental infection before 35 days results in embryo resorption and irregular returns to estrus. Between days 35 and 70, infection kills fetuses and results in an increase in mummies. After 70 days, fetuses can mount an immune response and so may survive infection. Reproductive failure is usually limited to younger sows
 C. Diagnosis is based on an increase in mummies and irregular returns to estrus, confirmed by evidence of PPV antigen in lungs of mummified fetuses
 D. Control of PPV requires prebreeding vaccination of all susceptible breeding stock

II. PRRS virus
 A. Once transmitted to the tonsils and upper respiratory tract, the virus becomes systemic and has a predilection for lymphoid tissues. It is secreted in nasal secretions, urine, feces, milk, and semen
 B. Reproductive evidence of PRRS virus infection includes an increase in regular and irregular returns, abortion at any stage of gestation, premature farrowing, and an increased preweaning mortality
 C. Fetal mortality may be due to umbilical arteritis, resulting in hypoxia
 D. Diagnosis is based on clinical signs (reproductive and respiratory) and confirmed by serology, PCR, or virus isolation
 E. There is no single control strategy, but management must strive for a comprehensive sow immune status to reduce or eliminate virus shedding. Vaccine is available

III. Leptospirosis
 A. Leptospira adapted to pigs include *L. interogans* serogroup Australis (especially serovar *bratislava*) and serogroup Pomona, serovar *Pomona*. Other serovars can also infect pigs

B. Once infected, a leptospiremia occurs and the organisms locate in the kidney, the male reproductive tract, the uterus, and, with *L. bratislava*, the oviducts
C. Clinical signs include an increased estrus return rate (especially *L. bratislava*) and late-term abortion (*L. pomona*)
D. Diagnosis is usually based on serology after evidence of reproductive disease
E. Abortions may be prevented and renal carriers eliminated by parenteral streptomycin
F. Treatment can be given 1 week before breeding and 2 wks before farrowing. Vaccines are available

Supplemental Reading

Fubini SL, Ducharme NG. *Farm Animal Surgery*. St Louis, 2004, Saunders.
Jackson PGG, Cockcroft PD. *Handbook of Pig Medicine*, Oxford, UK, 2007, Saunders.
Radostits OM, et al. *Veterinary Medicine: A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats*, 10th ed. Oxford, UK, 2007, Saunders.
Youngquist RS, Threlfall WR. *Current Therapy in Large Animal Theriogenology*, 2nd ed. St Louis, 2007, Saunders.

Poultry Medicine and Management

53 CHAPTER

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GENERAL INFORMATION

The field of poultry medicine is considered to be a somewhat specialized field because many commercial companies employ veterinarians on staff. Most private practitioners will not be involved in commercial poultry medicine but instead may be called on to assist owners of backyard, hobby, and exhibition flocks.

The commercial poultry industry uses few medications in their birds. However, the industry does employ numerous vaccinations and biosecurity in an attempt to prevent most diseases. Rarely will commercial poultry have nutritional problems, whereas small flock owners may have deficiencies in their birds. Small flock owners often attempt to treat their birds with little if any consultation other than that offered by the local feed store or hardware store employees. In addition, many small flock owners may have great difficulty finding vaccines for use in their flock. Biosecurity practices can be used to assist small flock owners control disease. However, because many small flocks are composed of multiple ages and species, the principles might not work as well as in the commercial industry.

This review outline is a guide for veterinarians in preparing for the poultry medicine examination questions. Information is included to help in the understanding of both the commercial poultry industry and small flocks. Numerous diseases can seen in poultry; the review outline lists those most commonly seen.

POULTRY RESTRAINT

I. Physical
 A. Several types of poultry may be kept as hobby pets, including the following: Chickens, turkeys, waterfowl, game birds, guinea fowl, and pigeons
 B. Most domestic poultry are reasonably docile and easy to handle
 C. Dangers
 1. To the handler: Being pecked, scratched, hit by a wing, spurred
 2. To the bird: Wing fractures, leg fractures, panic, suffocation, escape
 D. Methods
 1. Chickens
 a. Simultaneously grab chickens by the leg and wing
 b. Carry chickens by both legs
 c. Hold both legs of chickens and support body with palm of hand
 d. Hold chickens next to your body while holding both legs
 e. Blindfold the eyes of chicken
 f. Interlock wings of chicken over back
 g. Care must be taken to not interfere with respiration
 2. Turkeys
 a. Grasp and hold small birds similar to holding chickens
 b. Grasp large turkeys by both legs and allow them to rest on their keel
 c. Lift by holding one wing and both legs
 d. Do not lift heavy turkeys by their legs only
 3. Waterfowl
 a. Capture with nets or hooks
 b. Support the head and neck of the bird when lifting
 c. Can be held with the head tucked under the handler's arm with the bird's body against the handler while holding both legs of the bird with one hand
 4. Pigeons and quail
 a. Usually held in one hand similar to holding a small chicken, with the palm of the hand supporting the ventrum of the bird and the legs held between the fingers of the same hand
 b. Birds may also be held in the palm with the ventrum of the bird in the palm and the bird's feet and legs extended away from the palm
 c. Pigeons and quail often escape easily
 d. When holding in one hand, care must be taken to not interfere with respiration
II. Chemical restraint
 A. Seldom needed in most poultry
 B. Ketamine and isofluorane gas are excellent

HUSBANDRY

I. Nutrition
 A. Anatomy
 1. All poultry have no teeth for grinding food
 2. Food is grasped with the beak
 3. The crop, an extra thoracic diverticulum of the esophagus, acts as a short-term storage organ for food. Digestion of starch is initiated here
 4. Poultry have a muscular stomach (the ventriculus or gizzard) for grinding food smaller

5. Poultry have a glandular stomach (proventriculus) for digestion
 a. HCl converts pepsinogen to pepsin
 b. Pepsin digests protein
6. Most digestion occurs in the small intestines
7. Some fiber digestion is in the paired cecae
8. Feces excreted into cloaca

B. Commercial diets
1. Feed is the greatest cost associated with poultry meat and egg production
2. Commercial poultry companies have feed mills to prepare diets
3. Diets are least-cost rations
4. Diets vary between industry segments and poultry companies
5. Poultry diets are usually crumbles or pellets
6. Seldom have diet-related diseases or problems in commercial industry
7. Several diets may be used throughout the life of a flock
 a. Starter diet
 b. Grower ration
 c. Maintenance ration
 d. Finisher ration

C. Backyard, hobby, exhibition diets
1. Grains
2. Commercially prepared diets available from local feed store
3. Prepare own diets using grains, supplements, other ingredients.
4. Diets may not be least cost

II. Housing

A. Types
1. Broiler
 a. Raised in same house for brooding and grow out
 (1) Single age on farm
 (2) "All in all out" to reduce disease
 b. Length and width vary with company. Trend toward longer and wider houses
2. Commercial table egg
 a. Environmentally controlled houses
 b. Single- or similar-age farm
 c. Birds brooded in one house, then moved to layer house
 (1) Moved at 18 to 20 weeks
 (2) Chickens are housed in cages
 (3) Multitiered cages (more birds per house)
3. Turkeys
 a. Similar housing style as broilers
 b. House width and length may vary
 c. Multiage farms
 (1) Brooded in one house for 8 weeks
 (2) Moved to grow out house on farm at 8 weeks
4. Backyard, hobby, exhibition poultry
 a. No standard housing
 b. May be allowed free range on the premise
 c. Various ages and species may be on the premises
 d. Housing size may vary with the breed kept
 (1) Standard-size breeds
 (2) Bantams

B. Ventilation
1. Reduce noxious gases, dust, moisture, and pathogens
2. Types
 a. Mechanical
 (1) Fans in the house to move air in or out
 (2) Fans move air from one end of the house (tunnel effect)
 b. Natural
 (1) Curtain sides that can be raised or lowered
 (2) Wire pens instead of solid sides (hobby flocks)

C. Litter and bedding
1. Used to dilute feces, absorb moisture, comfort
2. Usually wood shavings or rice hulls
 a. Other substances can be used commercially and in hobby flocks
 b. Many hobby flocks are allowed free range to dirt or pasture
3. May be used for more than one flock
4. Typically not used in cage layers
 a. Wire floors or slat floors used
 b. Manure collected in lagoons or pits or allowed to dry beneath cages
5. Disposal of litter may be an environmental problem

D. Lighting types
1. Natural only: Usually only hobby flocks
2. Natural supplemented with artificial
 a. Commercial poultry industry
 b. Some hobby, exhibition flocks
3. Total environmentally controlled housing used
 a. Maximize egg production
 b. Maximize growth and feed conversion

POULTRY MANAGEMENT

I. Broiler industry

A. Genetic stock
1. Male and female lines
2. Obtained from genetic companies
3. White chickens developed as crosses of various meat types
 a. Cornish
 b. White or barred Rocks

B. Breeder flocks
1. Produce eggs to be hatched as broilers
2. Male and female lines
3. Multiplier vaccinations given throughout life
 a. Hyperimmunize progeny via egg yolk
 b. Prevent egg production losses
4. Eggs are set in company hatcheries
 a. Incubated at 99.5° F
 b. Incubation period is 21 days
 c. In ovo vaccinated using in ovo technology
 (1) 18 days of incubation
 (2) Marek disease
 (3) Infectious bursal disease
 d. Chicks hatch in hatchers

e. Chicks vaccinated at day 1 in spray cabinets
(1) Newcastle disease
(2) Infectious bronchitis

C. Grower farms (broilers)
1. Chicks delivered to farms from company hatcheries
2. Chicks grown under controlled conditions
a. Lighting
b. Ventilation
c. Heating and cooling
d. Feeding programs
3. Chicks brooded in house and grown in same house
4. Processed at 36 to 42 days of age, depending on use
a. Whole bird
b. Further processing
5. Bird totals on farms may be more than 100,000

II. Table-egg industry
A. Genetic stock
1. Male and female lines. Various characteristics from each line
2. Leghorn types: White eggs
3. Rhode Island red: Brown eggs

B. Commercial table-egg flocks (caged layers)
1. Obtain day old pullets from genetic companies or hatch eggs from genetic companies
2. Raise pullets under controlled lighting and feeding programs
3. Pullets moved to environmentally controlled lay houses at 16 to 18 weeks of age
a. Cages
b. Bird per cage density varies
4. Egg production starts about 18 to 20 weeks of age
5. Birds are vaccinated multiple times during their life
a. At time of movement to lay house
b. While in lay house to prevent egg production losses
6. Birds may be molted
a. Molting is a normal process of feather replacement
b. Layers are stimulated to molt
7. Birds are in production 65 to 110+ weeks
8. Many companies have million+ bird complexes

III. Turkey industry
A. Genetic stock
1. Genetic stock originally from genetic companies
2. Breeder flocks produce eggs that are used for commercial (production) turkeys
3. Breeder hens are artificially inseminated
4. Hens usually produce 80 to 100 eggs during a lay cycle
5. Birds are housed in environmentally controlled houses
6. Eggs are hatched in company hatcheries
a. Incubation temperature is 99.5° F
b. Incubation period is 28 days

B. Commercial production flocks
1. Poults obtained from commercial company hatcheries
2. Male and female turkeys are grown separately
3. Brooded in brooder houses until 8 weeks of age
4. Moved to grow-out houses at 8 weeks of age
5. Males usually grown until 18 to 20 weeks of age
6. Females usually grown until 16 to 18 weeks of age
7. Processing age determined by product use
8. Vaccinated multiple times during life
9. Several rations used during life of flock

IV. Backyard, hobby, exhibition poultry
A. Genetic stock
1. Obtained from specialized hatcheries, hardware stores, feed stores
2. Obtained from other hobby flock owners
3. May be pure-bred stock
a. Meat breeds
b. Egg breeds
c. Dual-purpose breeds
4. May be mixed stock
5. Birds may be kept for purely recreational reasons or aesthetics

B. Exhibition stock
1. Many birds are selected for specific exhibition characteristics
2. Investment in these birds may be time and money
a. Often these birds are selected over many generations
b. Value is often more than economics

COMMON POULTRY DISEASES

I. Bacterial diseases
A. Colibacillosis
1. Cause is *Escherichia coli*
2. Usually is opportunistic
3. Any age or species of poultry can be affected
4. Signs dependent on organ system affected
a. Unthrifty, weight loss, anorexia
b. Diarrhea
c. Respiratory signs (cough, rales, sneeze, gasping)
d. Sudden death without other signs
e. Difficulty walking
5. Lesions
a. Air sacculitis and pneumonia (fibrinous inflammation)
b. Enteritis (reddening of intestine with mucus)
c. Septicemia
(1) Fibrinous exudate on liver, pericardial sac
(2) Petechial hemorrhages on affected organs
d. Synovitis and arthritis
e. Omphalitis
f. Coligranuloma
6. Diagnosis
a. Signs and lesions (presumptive diagnosis)
b. Isolation of bacteria (confirmation)
7. Treatment
a. Antibiotic sensitivity
b. Broad-spectrum antibiotics

c. Cannot be used in commercial poultry
d. Many drugs are not approved for poultry
8. Prevention and control
a. Sanitation, disinfection
b. Biosecurity

B. Fowl cholera (pasteurellosis)
1. Cause is *Pasteurella multocida*
2. May be an acute or chronic disease in poultry
3. Signs: Unthrifty, ruffled feathers, anorexia, sudden mortality, inability to walk, dyspnea, mucoid discharge from mouth, fever
4. Lesions
a. No lesions in some cases of acute mortality
b. Weight loss
c. Septicemia
d. Swollen inflamed joints
e. Swollen face and wattles
f. Pneumonia and air sacculitis
g. Necrotic foci in liver
5. Diagnosis
a. Signs and lesions (presumptive)
b. Isolation of bacteria (confirmation)
6. Treatment
a. Antibiotic sensitivity
b. Broad-spectrum antibiotics
c. Commercial poultry may not be treated
7. Prevention and control
a. Best management practices
b. Sanitation and disinfection
c. Biosecurity
d. Bacterins

C. Infectious coryza
1. Cause is *Hemophilus paragallinarum*
2. Usually seen in chickens
3. Any age can be affected
4. Signs
a. Serous or mucoid discharge
(1) Eyes
(2) Nostrils
b. Unthrifty, weight loss, anorexia
c. Diarrhea
d. Respiratory signs (rales, cough, gasping)
e. Foul odor
f. Drop in egg production
5. Lesions
a. Catarrhal inflammation of sinuses
b. Swollen face and wattles
c. Conjunctivitis and infraorbital sinusitis
d. Air sacculitis, tracheitis, and pneumonia
(1) Rare instances
(2) May result in condemnation of carcass
6. Diagnosis
a. Signs and lesions (presumptive)
b. Isolation of bacteria (confirmation)
c. Serology
d. Polymerase chain reaction test (PCR)
7. Treatment
a. Antibiotic sensitivity
b. Broad-spectrum antibiotics
(1) Relapses may occur
(2) Cannot not be used in commercial poultry
8. Prevention and control
a. Sanitation, disinfection
b. Biosecurity
c. Bacterins

D. Salmonellosis
1. Pullorum disease
a. Cause is *Salmonella pullorum*
b. Any age can be affected
c. Usually seen as a problem in chicks and turkey poults
d. Bacteria is egg transmitted and spreads horizontally
e. Rarely a problem in industry
(1) National Poultry Improvement Plan testing
(2) Destruction of positive birds
f. Signs
(1) Usually only in young birds
(2) Depression
(3) White diarrhea
(4) Huddling
(5) Some will show no signs
g. Lesions
(1) None
(2) Enteritis with cecal cores
(3) Emaciation
(4) Necrotic foci in organs
(5) Retained egg yolks
(6) Blighted ova in hens
h. Diagnosis
(1) Serology: Rapid whole-blood agglutination
(2) Isolation and identification of bacteria
i. Treatment
(1) Not recommended
(2) Destruction of positive birds
j. Control and prevention
(1) National Control Program participation
(2) Elimination of carrier birds
2. Fowl typhoid
a. Cause is *Salmonella gallinarum*
b. Any age can be affected
c. Affects most poultry species
d. Bacteria is egg transmitted and spreads horizontally
e. Rarely a problem in industry
(1) National Poultry Improvement Plan testing
(2) Destruction of positive birds
f. Signs
(1) Sudden death
(2) Depression
(3) Yellow or green diarrhea
(4) Decreased appetite
(5) Increased thirst
g. Lesions
(1) Pale comb and face
(2) Enlarged mottled yellow-green liver
(3) Emaciation
(4) Necrotic foci in organs
(5) Lesions are similar to those of pullorum disease

h. Diagnosis is same as for pullorum disease
i. Treatment is same as for pullorum disease
j. Control and prevention are the same as with pullorum disease

E. Gangrenous dermatitis
1. Caused by clostridial bacteria (usually *Clostridium perfringens*)
2. Usually seen in young, growing birds
3. May be secondary to immunosuppressive diseases
4. Rarely seen in backyard and hobby flocks of birds
5. Signs
a. Sudden mortality
b. Unthrifty
c. Depression
d. Inappetance
e. Difficulty walking (leg weakness)
6. Lesions
a. Dark, moist, edematous skin patches
b. Discoloration of underlying muscles
c. Internal organs may be swollen
7. Diagnosis
a. Gross lesions (presumptive diagnosis)
b. Isolation of bacteria (confirmation)
c. Histopathology of lesions
8. Treatment
a. Various water acidifiers are used
b. Broad-spectrum antibiotics
(1) Use often in both feed and water
(2) May be ineffective
c. Culling of affected birds
9. Prevention and control
a. Sanitation, disinfection
b. Biosecurity
c. Control immunosuppressive diseases
d. Best management practices
e. Litter management to control moisture
f. Minimize overcrowding and trauma

F. Mycoplasmosis
1. Chronic respiratory disease
a. Cause is *Mycoplasma gallisepticum* (MG)
b. Egg-transmitted bacteria; also spreads horizontally
c. Mortality is usually low in uncomplicated disease
d. Signs
(1) Coughing
(2) Sneezing
(3) Nasal discharge
(4) Egg-production losses
(5) No signs in carriers
e. Lesions
(1) Air sacculitis
(2) Swollen sinuses
(3) Foam in eye
(4) Thick clear to gray nasal or eye exudate
(5) Fibrinopurulent exudate on liver and pericardium
f. Diagnosis
(1) Serology
(2) Isolation of bacteria
(3) PCR testing
g. Treatment
(1) Antibiotics may be used commercially to decrease losses until slaughtered
(2) Antibiotics may be used in backyard and hobby flocks, but outbreaks may recur
h. Prevention and control
(1) Serologic testing for positives
(2) Elimination of positives
(3) Sanitation and disinfection
(4) Best management practices
2. Infectious synovitis
a. Cause is *Mycoplasma synoviae*
b. Egg-transmitted bacteria; also spreads horizontally
c. May be a respiratory infection or synovial infection
d. Signs
(1) Lameness
(2) Decreased growth and performance
(3) Rales
(4) Egg-production losses
(5) No signs in carriers
e. Lesions
(1) Air sacculitis
(2) Thick, sticky synovial exudate
(3) Swollen joints or footpad
(4) Sinusitis
f. Diagnosis is the same as for MG
g. Treatment is the same as for MG
h. Prevention and control are the same as for MG

G. Necrotic enteritis
1. Etiology is *Clostridium perfringens*
2. Seen in turkeys and broilers (rarely in backyard birds)
3. Usually seen in young growing broilers
4. May be seen secondary to coccidiosis outbreaks
5. Signs
a. Sudden mortality without signs
b. Depression
c. Appetite reduction
d. Diarrhea
e. Ruffled appearance
6. Lesions
a. Enteritis (usually jejunum and ileum)
b. Distension of intestines with gas
c. Blood in intestines
d. Pseudomembrane present in intestines
e. Thickened intestinal mucosa
7. Diagnosis
a. Typical lesions (presumptive diagnosis)
b. Bacterial isolation and identification (confirmation)
8. Treatment
a. Broad-spectrum antibiotics in feed or water
b. Probiotics
9. Prevention and control
a. Sanitation, disinfection
b. Biosecurity
c. Coccidiosis control

H. Ulcerative enteritis, also called quail disease
1. Etiology is *Clostridium colinum*
2. Usually seen in quail and upland game birds
3. May be seen in other poultry on occasion
4. Death losses in quail can be exceptionally high in an outbreak
5. Signs
a. Sudden mortality without signs
b. Depressed and listless
c. Appetite reduction
d. Diarrhea
e. Dull ruffled appearance. "Humped up"
f. Reluctant to move
6. Lesions
a. Severe emaciation
b. Pinpoint necrotic foci in liver
c. White "cauliflower"-like ulcerations in intestines
d. Ulcerations may perforate the intestinal wall
e. Peritonitis
7. Diagnosis
a. Typical lesions (presumptive diagnosis)
b. Bacterial isolation and identification (confirmation)
c. Histopathology
8. Treatment
a. Broad-spectrum antibiotics in feed or water
b. Probiotics may be useful
9. Prevention and control
a. Sanitation, disinfection
b. Biosecurity
c. Raise quail on wire

II. Viral
A. Newcastle
1. Etiology is a *Paramyxovirus*
2. Numerous strains of *Paramyxoviruses* exist
3. Strains vary greatly in virulence
4. Exotic Newcastle disease is referred to as END
5. There is currently some confusion as to exactly the term for nonexotic forms of Newcastle disease
6. Virus is zoonotic (conjunctivitis)
7. Signs: Two forms of the disease will be listed
a. END or virulent Newcastle (vEND)
(1) Sudden high mortality
(2) Increased respiration
(3) Weakness
(4) Diarrhea
(5) Central nervous system (CNS) signs (paralysis, paresis, tremors)
b. Endemic or less virulent Newcastle disease
(1) Depression
(2) Egg-production losses (soft, irregular eggs)
(3) Respiratory (coughing, gasping, sneezing)
(4) Gasping
(5) CNS signs (paralysis, twisting of neck)
8. Lesions: Depend on form and virus virulence
a. Exotic
(1) Severe tracheitis
(2) Mucoid discharge from mouth
(3) Hemorrhagic or necrotic intestinal foci
(4) Hemorhhagic or necrotic cecal tonsils
(5) No pathognomonic lesions
b. Endemic
(1) No lesions
(2) Mild air sacculitis
(3) Mild tracheitis
9. Diagnosis
a. Signs and lesions are helpful
b. Serology
c. Virus isolation and characterization
d. PCR test
10. Treatment
a. None
b. vEND is reportable and flock quarantined
11. Prevention and control
a. Vaccination
(1) Used for endemic Newcastle
(2) Not used for vEND in U.S. poultry
(3) Hobby flock owners may have difficulty obtaining vaccine
b. Sanitation, disinfection
c. Biosecurity
d. Elimination of birds infected with vEND

B. Avian influenza
1. Cause is an Orthomyxovirus
2. Subtyped based on hemagglutinin and neuraminidase
3. 15 hemagglutinin and 9 neuraminadase subtypes
4. H5 and H7 subtypes are important poultry types
5. H5N1 is the current "bird flu" of concern and is zoonotic
6. Mildly pathogenic and highly pathogenic forms
7. Signs depend on form
a. Highly pathogenic
(1) Sudden high mortality
(2) Drop in water and feed consumption
(3) Weakness
(4) Tremendous drop in egg production
(5) Nervous signs (paralysis, paresis, torticollis)
(6) Respiratory signs (coughing, sneezing, rales)
b. Mildly pathogenic
(1) None
(2) Egg-production drop
(3) Respiratory (coughing, rales, sneezing)
(4) Nonspecific signs
8. Lesions depend on the form and virulence of the virus
a. Highly pathogenic
(1) Hemorrhagic lesions in organs and skin
(2) Necrotic lesions in organs and skin
(3) Swelling, hemorrhages, and necrotic lesions of face and comb
(4) Hemorrhagic, necrotic cecal tonsils
(5) Lesions may resemble vEND lesions
b. Endemic
(1) No lesions
(2) Air sacculitis
(3) Tracheitis
(4) Sinusitis

9. Diagnosis
 a. Signs and lesions are helpful
 b. Serology
 c. Virus isolation and characterization
 d. PCR test
10. Treatment
 a. None
 b. Avian influenza is reportable and flock quarantined
11. Prevention and control
 a. Biosecurity
 b. Sanitation, disinfection
 c. Elimination of birds infected with influenza
 d. Vaccination
 (1) Used in limited circumstances in United States
 (2) Inactivated vectored vaccine is licensed for use
 (3) Hobby flock owners may have difficulty obtaining vaccine

C. Avian pox
1. Cause is Avian pox virus
2. Spread by mosquitoes and contact with dried scabs
3. Any age or species of poultry can be affected
4. Signs: Two forms of the disease occur
 a. Cutaneous or "dry pox"
 (1) Decreased growth
 (2) Production drop
 (3) Unthrifty birds
 (4) Weight loss
 b. Diphtheritic or "wet pox"
 (1) Decreased growth
 (2) Production losses
 (3) Weight loss
 (4) Gapping
5. Lesions depend on form
 a. Cutaneous pox
 (1) Start as blister-like lesions on unfeathered areas
 (2) Progress to wartlike or scablike lesions
 b. Diphtheritic or "wet pox"
 (1) Wart or "cauliflower-like" lesions
 (2) Lesions in mouth, oropharynx, corner of beak
 (3) May involve eye region
6. Diagnosis
 a. Signs and lesions
 b. Histopathology
7. Treatment
 a. None
 b. Topical antibiotics
 c. Diphtheritic pox may cause high mortality
8. Prevention and control
 a. Vaccination
 (1) Commercial poultry use vaccine
 (2) Hobby flock owners may have difficulty obtaining vaccine
 b. Sanitation, disinfection
 c. Biosecurity
 d. Mosquito control

D. Infectious bronchitis
1. Cause is a coronavirus
2. Affects chickens of all ages
3. Rapidly spreading disease
4. Signs
 a. Dyspnea
 b. Coughing and gasping
 c. Rales
 d. Egg-production losses
 (1) Tremendous drop over a few days
 (2) Losses might not be noticed in hobby flocks
 e. Depression
 f. Sneezing
5. Lesions
 a. Air sacculitis
 b. Swollen kidneys with urate deposits
 c. Tracheitis
 (1) Serous
 (2) Catarrhal
 (3) Caseous
 d. Rough, thin eggshells
 e. Watery egg albumen
6. Diagnosis
 a. Clinical history and lesions
 b. Histopathology
 c. Serology
 d. Virus isolation
7. Treatment is of little value
8. Prevention and control
 a. Biosecurity
 b. Vaccination
 (1) Used extensively in table-egg chickens
 (2) Numerous strains used in commercial poultry
 (3) Hobby flock owners might have difficulty obtaining vaccine or might not vaccinate
 c. Sanitation, disinfection
 d. Best management practices

E. Infectious bursal disease, also called "gumboro"
1. Caused by a Birnavirus
2. Primarily in chickens
3. Immunosuppressive disease of young chicks
4. Signs
 a. Ruffled feathers
 b. Diarrhea
 c. Vent picking
 d. Huddling
 e. Mortality
 f. Straining to defecate
 g. Loss of appetite
5. Lesions
 a. Blood in feces
 b. Dehydration
 c. Swollen bursa of Fabricius
 (1) Discolored
 (2) Gelatinous film
 (3) Necrotic areas
 d. Swollen organs
 e. Leg muscle hemorrhages

6. Diagnosis
 a. Signs and lesions
 b. Histopathology
 c. Serology
7. No treatment
8. Prevention and control
 a. Vaccination
 b. Biosecurity
 c. Sanitation and disinfection
 d. Best management practices

F. Infectious laryngotracheitis
1. Etiology is a Gallid herpes virus type 1
2. Affects chickens, pheasants, and peafowl of various ages
3. May be listed as a reportable disease in the state
4. Signs
 a. Dyspnea
 b. Coughing and gasping
 c. Rales
 d. Production losses
 e. Mortality
5. Lesions
 a. Increased lacrimation
 b. Conjunctivitis
 c. Tracheitis
 (1) Bloody
 (2) Caseopurulent plug
 d. Swollen sinuses
6. Diagnosis
 a. Signs and lesions
 b. Histopathology
 c. Serology
 d. PCR
7. Treatment is of no value
8. Prevention and control
 a. Biosecurity
 b. Vaccination
 (1) May be restricted
 (2) Hobby flock owners may have difficulty obtaining vaccine
 c. Sanitation, disinfection

G. Marek disease (range paralysis)
1. Cause is a cell-associated herpes virus
2. Usually a disease of young chickens
3. Lymphoproliferative disease of chickens
4. Several types of the disease can be seen
 a. Nerve form
 b. Skin form
 c. Ocular form
5. Signs
 a. Paralysis, usually leg
 b. Ruffled feathers
 c. Blindness
 d. Mortality
 e. No signs
6. Lesions
 a. Swollen, discolored peripheral nerves
 b. Nerves are infiltrated with lymphocytes
 c. Rough, raised feather follicles
 d. Feather follicles are infiltrated with lymphocytes
 e. Gray discoloration of iris
 f. Iris is infiltrated with lymphocytes
 g. Lymphomas of other organs
7. Diagnosis
 a. Signs and lesions
 b. Histopathology
 c. Serology
 d. PCR
 e. Virus isolation
8. Treatment is of no value
9. Prevention and control
 a. Biosecurity
 b. Vaccination
 c. Sanitation, disinfection
 d. Selection of breed stock for resistance

H. Lymphoid leukosis-sarcoma complex
1. Cause is an α-retrovirus
2. Chickens are the natural host
3. The virus is egg transmitted and horizontally from bird to bird
4. Signs
 a. Nonspecific
 b. Weakness
 c. Appetite loss
 d. Production losses
 e. Unthriftiness
 f. Mortality
 g. No signs
 h. Signs also depend on organ affected with lymphomas
5. Lesions
 a. Lymphoma in organs
 b. Erythroblastosis
 c. Osteopetrosis
 d. Fibromas
 e. Other tumors
6. Diagnosis
 a. Lesions
 b. Histopathology
 c. Serology
 d. PCR
7. Treatment is of no value
8. Prevention and control
 a. Biosecurity
 b. Eradication of positive birds
 c. Resistance selection
 d. Sanitation, disinfection

III. Parasitic

A. External parasites and pests: Several species of arthropods are external parasites of poultry. In many areas of the country, insect pests may be a problem. One of the chief effects of external parasites is irritation of the bird. Some external parasites do injure the host by sucking blood or lymph. These effects may result in a decreased appetite, weight loss, egg-production loss, restlessness, anemia, feather damage, and in some instances mortality
1. Several lice species are poultry external parasites
 a. Most species are chewing lice
 b. The life cycle is entirely on the bird
 c. Lice are usually found near the vent, on the head, and under wings

d. Lice attach eggs (nits) to the feathers
e. Young birds are more severely affected than adults are
f. Several chemicals (dusts, sprays, impregnated strips) are available for control

2. Several species of mites commonly infest poultry
a. All species suck blood
b. The common chicken mite or red mite (*Dermanyssus gallinae*) feeds on the bird at night and spends the day hiding in cracks and crevices of the poultry house or roosts
c. The northern fowl mite (*Ornithonyssus sylviarum*) remains on the bird continuously
d. Scaly leg mites (*Knemidocoptes mutans*) live under the skin of the legs, causing thickening of the scales and hyperkeratosis
e. Several chemical products are available for control

3. Other external parasites
a. Fowl ticks (*Argus persicus*) are soft-bodied ticks that suck blood. Control requires premise treatment
b. Chiggers are Trombiculid mites, which may feed on poultry kept outside
c. Mosquitoes suck blood and transmit fowl pox virus
d. Black flies (*Simulium* spp.), also called turkey or buffalo gnats, may attack poultry. These bloodsucking gnats cause severe irritation and even death

B. Internal parasites: Numerous species of helminths affect poultry. The nematode group is by far the most common group of helminth parasites. Poultry may have few signs when a mild infection of internal parasites is present. Signs of infection include weight loss, unthriftiness, poor growth, diarrhea, droopiness, and death. Internal parasites are more commonly a problem in backyard, hobby, and exhibition poultry flocks. Few anthelminthics are approved for poultry; often extralabel use is done (especially hobby-type flocks)

1. Ascarids
a. Ascaridia are common in poultry
b. Older birds are somewhat resistant to infections
c. Direct life cycle
d. Present in small intestines
e. Large, heavy-shell egg is visible on fecal flotation

2. Threadworms (*Capillaria* spp.)
a. Several species found in poultry
b. Found in crop (ingluvia) and small intestines
c. Some have a direct life cycle (others have indirect)
d. Eggs are operculated and found on fecal flotation

3. Cecal worm
a. This worm (*Heterakis gallinarum*) lives in the cecae
b. Usually asymptomatic in infected poultry
c. Vector of *Histomonas meleagridis* (blackhead)
d. Direct life cycle
e. Eggs visible on fecal flotation

4. Tapeworms
a. Many genera can infect poultry
b. Flat, ribbon-shaped worms may be visible on necropsy
c. Infected birds may be asymptomatic
d. Heavy infections may cause emaciation
e. Indirect life cycle

IV. Protozoan diseases

A. Coccidiosis

1. Cause is several species of *Eimeria*
2. Rarely seen in commercial poultry (coccidiostats use)
3. May be seen in backyard and hobby flocks that do not use commercial rations
4. Usually young birds affected
5. Coccidial oocysts are shed in feces
6. Signs
a. May be nonspecific
(1) Unthriftiness
(2) Poor growth
(3) Depression
b. Mucoid or bloody diarrhea
c. Dehydration
d. Egg-production drop
7. Lesions
a. Enteritis of varying degrees
b. Anemia
c. Intestinal edema and ulceration
d. Blood in intestines or cecae
e. Cheesy necrotic cores in cecae
8. Diagnosis
a. Gross lesions
b. Oocysts in feces or intestinal scrapings
c. Histopathology
9. Treatment
a. Anticoccidial drugs
b. Supportive care
10. Prevention and control
a. Coccidiostats
b. Sanitation and disinfection
c. Biosecurity

B. Histomoniasis (blackhead)

1. Caused by *Histomonas meleagridis*
2. Seen in commercial chickens, turkeys, and backyard, hobby, and exhibition-type flocks
3. Transmission
a. Direct from feces
b. Consumption of transport host (earthworms)
c. Ingestion of infected cecal worm (*Heterakis*) eggs
4. Can affect any age bird
5. Signs
a. Anorexia
b. Increased consumption of water
c. Depression
d. Droopiness
e. Yellowish feces or diarrhea
f. Cyanosis of face

6. Lesions
 a. Emaciation
 b. Circular, irregular depressed areas on liver
 c. Thickened, distended cecae
 d. Caseous cecal cores
7. Diagnosis
 a. Gross lesions are pathognomonic
 b. Histopathology
8. Treatment
 a. No drugs labeled for treatment
 b. Human drug (metronidazole) used extralabel
9. Prevention
 a. Worm control
 b. Do not keep chickens and turkeys together
 c. Nitarsone is approved as a preventative

C. Trichomoniasis
1. Cause is *Trichomonas gallinae*
2. Seen in pigeons, turkeys, chickens, and other birds
3. Referred to as "canker" in pigeons
4. Almost all pigeons are considered carriers
5. Signs: Loss of appetite, retarded growth, gaunt appearance
6. Lesions
 a. Yellow caseous plaques in upper gastrointestinal tract
 b. Lesions may become quite large
 c. Lesions may be visible at edge of beak
 d. Lesions may interfere with beak closure
7. Diagnosis
 a. Identification of protozoan pathogens in smears and scraping
 b. Histopathology
8. Treatment
 a. No drugs labeled for treatment
 b. Human drug (metronidazole) used extralabel
9. Prevention
 a. Removal of infected birds
 b. Sanitation and disinfection
 c. Biosecurity

V. Fungal

A. Aspergillosis
1. Caused by *Aspergillus* spp. (usually fumigatus species)
2. May be a hatchery contaminate
3. Usually young birds affected
4. Signs: Dyspnea, gasping, loss of appetite, ataxia, falling down, incoordination
5. Lesions
 a. Yellow-gray nodules in respiratory tract
 (1) Lungs
 (2) Air sacs
 (3) Trachea
 b. Fungal growth in air sacs
 c. Gray to white foci in CNS
 (1) Brain
 (2) Eye
6. Diagnosis
 a. Signs and lesions
 b. Histopathology
 c. Serology
 d. Fungal isolation and identification
7. Treatment
 a. Usually not done
 b. Eliminate affected birds
 c. Antifungals may be used in valuable birds
8. Prevention
 a. Sanitation and disinfection
 b. Best management practices

B. Candidiasis (thrush)
1. Sporadic infection caused by *Candida albicans*
2. Opportunistic yeast infection
3. May be seen in any poultry species or age
4. Signs: Nonspecific, retarded growth, ruffled feathers
5. Lesions
 a. Thickening of crop mucosa
 b. White plaques in oropharynx
 c. Hemorrhagic, necrotic mucosa of proventriculus
6. Diagnosis
 a. Gross and microscopic lesions in tissues
 b. Isolation and identification of fungus
7. Treatment
 a. Antifungals (extralabel use)
 b. Copper sulfate is sometimes used in the water
8. Prevention
 a. Sanitation and disinfection
 b. Prevention of other diseases
 c. Avoid overcrowding
 d. Stress reduction

VI. Other problems

A. Rickets
1. Deficiency or imbalance of calcium, phosphorous, and vitamin D
2. Rarely seen in commercial poultry
3. May be seen in backyard and hobby flocks that do not use commercial rations
4. Usually young birds affected
5. Signs: Varying degrees of lameness, retarded growth
6. Lesions
 a. Rubbery, soft bones and beak
 b. Beaded ribs
 c. Enlarged ends of bones
7. Diagnosis
 a. Gross and microscopic lesions in bones
 b. Diet analysis
8. Treatment: Supplementation with Ca, P, and vitamin D; diet correction
9. Prevention: Balanced rations, proper feed storage

B. Hypovitaminosis A
1. Deficiency of vitamin A
2. Rarely seen in commercial poultry
3. May be seen in backyard or hobby flocks that do not use commercial rations
4. Any age or poultry species could be affected
5. Signs: Production losses, weakness, ruffled feathers, growth retardation, incoordination
6. Lesions
 a. Sticky eyelids
 b. Watery eye and nasal discharge

 c. Caseous white eye exudate
 d. White plaques in oropharynx
7. Diagnosis
 a. Gross and microscopic lesions
 b. Diet analysis
8. Treatment
 a. Supplementation with vitamin A
 b. Diet correction
9. Prevention
 a. Balanced rations
 b. Proper feed storage

C. Vitamin E deficiency
1. Rarely seen in commercial poultry
2. May be seen in backyard and hobby flocks that do not use commercial rations
3. Any age or poultry species could be affected
4. Signs: Incoordination and falling over, weakness, ataxia, prostration, ventral edema
5. Lesions
 a. Encephalomalacia
 b. Edematous, discolored skin
 c. Muscular dystrophy
6. Diagnosis
 a. Gross and microscopic lesions
 b. Diet analysis
7. Treatment: Supplementation with vitamin E, diet correction
8. Prevention: Balanced ration, proper feed storage

D. Botulism: Often called "limberneck"
1. Caused by ingestion of *Clostridium botulinum* toxin
2. Seen in any age and species of poultry
3. Toxin can be found in decaying organic matter
4. Signs: Sudden mortality without signs; flaccid paralysis (neck, wings, legs); depression; loose, ruffled feathers
5. Lesions
 a. None
 b. Fly larvae in proventriculus or gizzard (larvae concentrate toxin)
 c. Feed, mucus, and dirt around beak
6. Diagnosis
 a. Signs and lack of lesions
 b. Toxin bioassay
7. Prevention and control
 a. Sanitation, disinfection
 b. Keep dead and decaying animals and plants removed

Supplemental Reading

Pattison M, et al. *Poultry Diseases*, 6th ed. Oxford, UK, 2008, Saunders.

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SECTION V EXOTICS

54 CHAPTER

Pet Birds

Nickol P. Finch

TYPES OF BIRDS

I. Ratites: Ostriches, emus, and rheas
II. Anseriformes: Ducks, geese, and swans
III. Falconiformes: Eagles, hawks, and falcons (meat-eaters)
IV. Galliformes: Chickens, turkeys, pheasant, and quail
V. Columbiformes: Pigeons and doves (produce crop milk)
VI. Psittaciformes
 A. Parrots
 1. Have a hooked maxilla and zygodactyl feet (two toes go forward and two back)
 2. Most are sexually monomorphic (cannot tell male from female by physical appearance)
 B. Loriidae: Lories and lorikeets (eat nectar)
 C. Cacatuidae: Cockatoos (have an erectile crest on the head)
 D. Psittacidae: Parrots and parakeets
VII. Strigiformes: Owls
VIII. Piciformes: Toucans
IX. Passeriformes: Song birds, finches, and ravens

For most of the remainder of this section, we refer to birds of the psittacine family unless otherwise noted.

ORIGIN

I. New World: Birds from South and Central America (e.g., Amazons, macaws)
II. Old World: Birds from Africa and Asia (African grays, Eclectus, lovebirds, and cockatoos)

HUSBANDRY

I. Caging
 A. Cage when not supervised; limits access to toxins, other pets, and possible dangers
 B. Bird should be able to flap without touching anything; provide horizontal space for flight for smaller birds
 C. Bar spacing should not allow escape or allow animal to get head caught between bars. Bars must be strong enough not to be bent by chewing. Homemade wire cages are often high in zinc, and most solders are high in lead
 D. Perches: Sandpaper perches result in foot sores
 E. Cage placement: Keep away from drafts, air vents, kitchen, and similar situations
II. Diet: Malnutrition is common in diets with mixtures of seeds, pellets, and human foods
 A. Seeds
 1. High in fat and usually high in vitamin E, but high fat content increases vitamin E requirements. Leads to obesity, fatty liver disease, egg binding
 2. Low in vitamin A, calcium, multiple B vitamins, iron, copper, and selenium
 3. Fortified seed diets apply supplement to seed hulls. Because seeds are hulled, birds consume little of the supplement
 B. Pellets
 1. Best choice for feeding usually. Switching to pelleted diets can be very difficult
 2. Colored pellets can change the color of feces; be aware of color preferences in birds
 C. Human foods: Consumption can lead to deficiencies or excesses similar to seed diets
 D. Supplements: Many are added to water, changing the taste, resulting in decreased water intake
III. Environmental considerations
 A. Smokers in the household, other birds or pets, presence of air fresheners or candles
 B. Cleaning practices, such as cage cleaning, food and water changing, examination of toys for damage

CLINICAL CONSIDERATIONS

I. Hands-off examination
 A. Observe from a distance first
 B. Evaluate behavior (perching, sitting on bottom of cage, tail bob, regurgitation, sleeping during the day)
 D. Evaluate eyes, nares, beak, feathers, attitude, posture, and feces without restraint
 E. Determine whether the animal can handle the stress of restraint. The bird may need to be

placed in oxygen or needs other supportive measures before restraint

II. Capture and restraint
 A. Use a towel for protection and to control wings
 B. Leather gloves are not generally considered appropriate for psittacines patients
 C. Catch the bird around the neck with the thumb in the intermandibular space and the fingers around the neck. For large birds, the second hand helps control the wings and wraps the towel around the body
 D. Make the room completely dark to facilitate capture
 E. Aggressive birds are best caught from a cat carrier turned on end

III. Hands-on examination
 A. Start from the head and work back. Evaluate eyes, nares, cere (the fleshy part that the nostrils are located in), feathers, lore (featherless area surrounding eye in some birds), and beak condition and shape
 B. Palpate wings and legs for fractures. Look at underside of wings for evidence of feather picking or chewing and examine for blood feathers (newly growing feathers). Check toenails and feet for length and injuries
 C. Palpate pectoral muscle for adequacy. If you cannot feel the keel through the overlying tissues, the animal is likely too fat. Differences between sides may indicate disuse or neurogenic atrophy
 D. Palpate abdomen. May feel ventriculus, which is hard and round. Hard, immobile structure may be an egg
 E. Evaluate sinuses, heart, lungs, and airsacs
 F. Can use a tongue depressor or speculum to open mouth

IV. Diagnostics
 A. Fecal examination
 1. Remember that colored foods can change the color of a bird's feces
 2. Psittacines typically possess 70% or more gram-positive bacteria, with a mixed colony of rods and cocci. Clostridia is not normal in psittacines' feces
 3. Yeast in the feces is a common finding in birds that eat bread products
 B. Blood collection (Figure 54-1)
 1. Nail clipping is not appropriate; samples are contaminated with feces or lymph, and it is painful
 2. Jugular vein: Usually exists in a featherless patch along the neck; right jugular is usually larger than the left but not always. Do not have to hold the vessel off; blood pressure is usually high enough to allow drawing without (except in very sick birds)
 3. Cutaneous ulnar (also known as basilic or brachial vein). Located at bend of elbow
 4. Medial metatarsal vein: Located on the inside of leg between tarsus and stifle. Usually have to hold the area off for a relatively long time
 C. Hematology and chemistry
 1. Complete blood cell count
 a. Packed cell volume (PCV): Essentially the same as PCV in mammals
 b. Heterophils: Equivalent of neutrophils in mammals. Increase with inflammation and infection; stress heterophilia is common
 c. Lymphocytes: Some birds normally have more lymphocytes than heterophils. True lymphocytosis occurs with chlamydophila or viral disease
 d. Monocytes: Monocytosis is common in chronic infection
 e. Eosinophils: May be increased with parasitism or tissue damage
 f. Basophils: Can be confused with toxic heterophils. Basophilia may occur in respiratory disease, resolving tissue damage, or chlamydophila infection
 2. Lactic dehydrogenase: Not liver specific; from muscle or liver
 3. Aspartate aminotransferase (AST): Liver, skeletal muscle, or cardiac muscle in origin. Low AST seen in advanced hepatocellular damage with fibrous replacement
 4. Alanine aminotransferase: Not useful in birds due to low activity
 5. Creatine kinase: From skeletal muscle, cardiac muscle, and nerve tissue
 6. Alkaline phosphatase: Elevated in bone disorders; not useful in liver disease
 7. γ-glutamyltransferase: Not sensitive for liver damage in birds
 8. Amylase and lipase: Not considered useful in birds at this time
 9. Uric acid: Elevated with renal disease or dehydration
 10. Creatinine: Not useful for renal disease. Elevated when feeding high-protein diets (often elevated in raptors)
 11. Urea: Not helpful in birds
 12. Calcium: Increased during egg production; decreased secondary to seed-based diets. African gray parrots are predisposed to low calcium
 13. Phosphorus: Renal disease is often not clinical until bird is very near death so increased phosphorus is not often appreciated
 14. Glucose: Hyperglycemia with stress, renal disease, diabetes mellitus. Hypoglycemia with starvation
 15. Cholesterol: High-fat diets may lead to high cholesterol; atherosclerosis may occur in birds. Most birds have fasting bile acids of less than 100 µmol/L
 16. Sodium: Increased with increased salt intake, dehydration, or salt poisoning
 17. Potassium: Increased with renal disease, severe tissue damage, or dehydration
 D. Radiographs
 1. Chemical restraint is often necessary
 2. Lightly applied masking tape is often used to facilitate positioning; remove tape by pulling

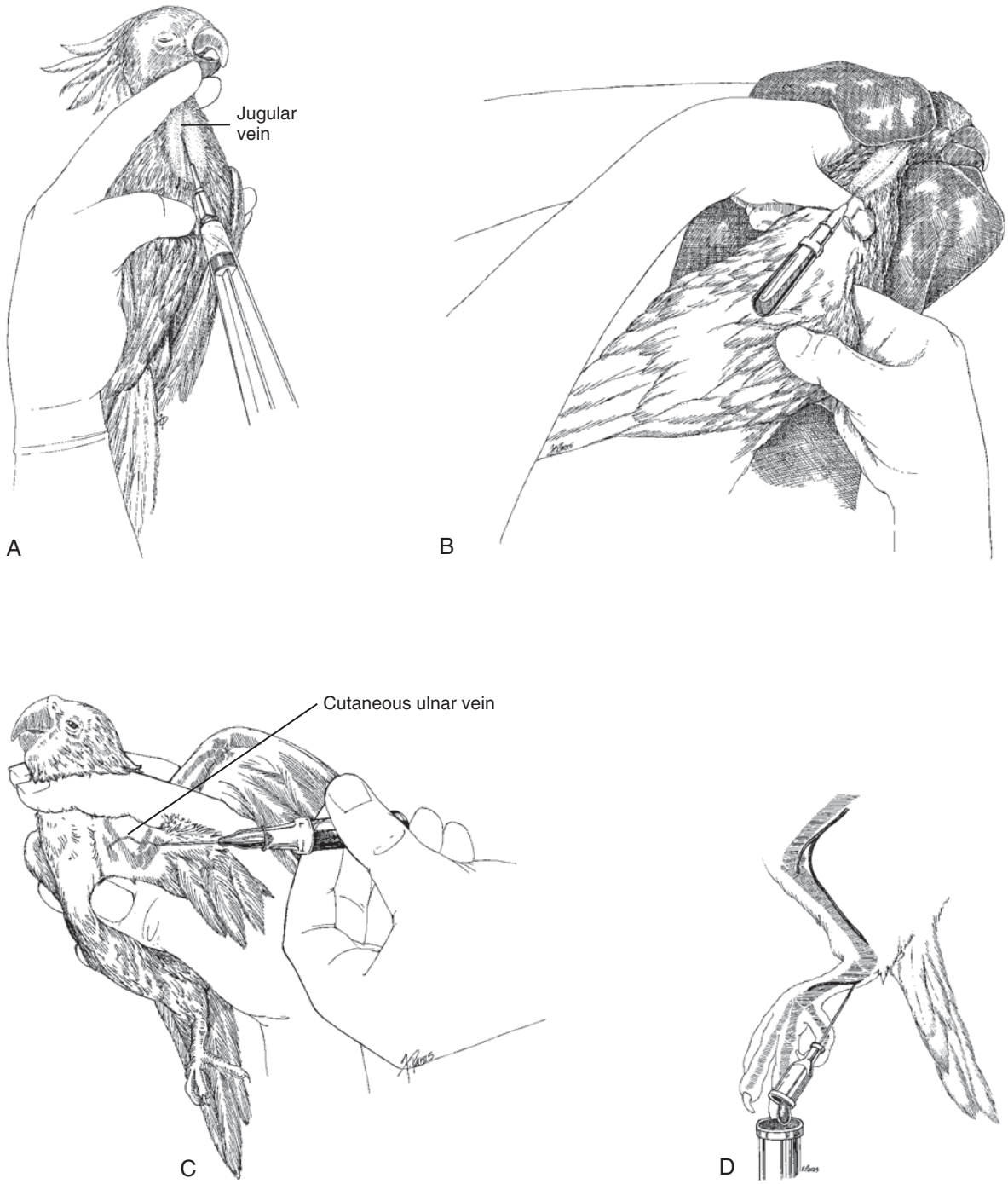


Figure 54-1 Venipuncture sites: **A,** Jugular vein, birds weighing less than 200 g. **B,** Jugular vein, larger birds. **C,** Cutaneous ulnar vein. **D,** Caudal tibial vein. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

with the feather growth. Make sure movement of chest (respiration) is not restricted

3. Normal anatomy
 a. Long bones normally have relatively thin cortices
 b. Trachea seen on right side of neck, and the lungs normally have a honeycomb appearance
 c. Do not mistake the great vessels for granulomas
 d. Crop may have food in it and is located just cranial to thoracic inlet
 e. Ventriculus lies in caudal abdomen behind the liver
 f. Kidneys are difficult to evaluate on radiographs
 g. Reproductive organs change dramatically in size, depending on reproductive activity. When active, testes or female tract can be mistaken for abdominal mass. Testes and ovaries are located at the cranial pole of the kidneys

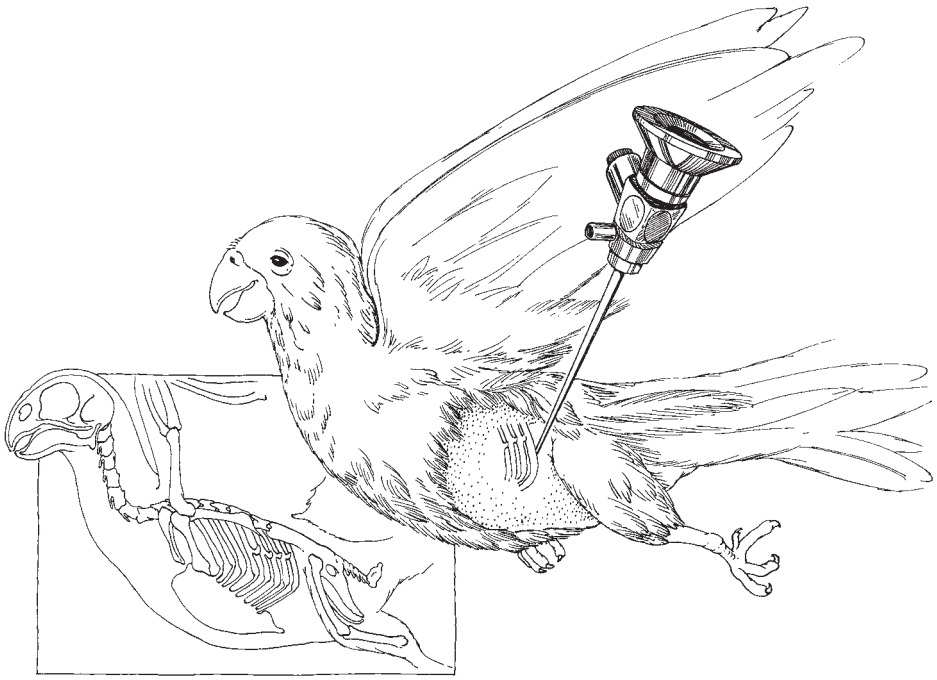


Figure 54-2 Preparation for endoscopy of the abdominal air sac; inset, trocar or cannula site. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

E. Ultrasound is more difficult in birds but can be used for obtaining biopsies
F. Ceolomic endoscopy: Uses the air sacs to allow visualization of organs (Figure 54-2)

V. Clinical techniques
A. Fluid therapy
1. Maintenance rate 50 mL/kg daily is used in most adult birds
2. Given subcutaneously (SC), intravenously (IV), intraosseous (IO), or orally (PO)
a. IV fluids given in jugular vein, cutaneous ulnar vein, or tarsal vein
b. IO is given in the ulna or tiba
c. Do not give more than 1 mL/30 g body weight. Use gavage tube

B. Medication administration
1. Intramuscular (IM) injections
a. Pectoral muscles: Most common site for IM injections, but do not use in racing pigeons or working falcons as irritation or pain to the pectoral muscle can greatly decrease flyability
b. Gastrocnemius muscles
(1) Smaller muscle that can be more difficult to isolate
(2) May result in temporary pain and reluctance to stand
2. IV injections can be given in locations listed for blood collection
3. PO administration: Unless the medication is something that tastes good, use a gavage tube to avoid potential aspiration
4. Nebulization: Good way to get drugs into the respiratory tract

C. Bandage and splint application
1. Figure-8 bandage (Figure 54-3) is used to immobilize anything from the elbow distally, including the radius, ulna, carpus, metacarpals, and

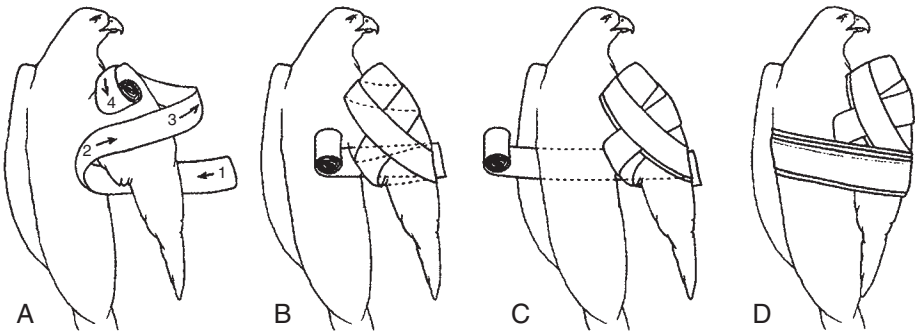


Figure 54-3 The figure-of-eight bandage is one of the most common and useful bandages placed on avian patients. (From Mitchell MA, Tully TN. *Manual of Exotic Pet Practice*, St Louis, 2009, Saunders.)

phalanges. If the shoulder or humerus is affected, add a bodywrap to stabilize affected areas
2. Robert Jones bandage
 a. Good for supporting damaged tissues. Thermoplastic materials can be used to make the bandage suitable for fracture stabilization
 b. Assure that the bandage is not too tight
3. Tape splint
 a. May be suitable as only coaptive device for leg fractures in small birds (less than 100 g)
 b. Used successfully in birds of 500 g if additional support is added
 c. In birds less than 50 g this is usually enough to immobilize the fracture
 d. Actively growing birds may have clinical union of fractures within 2 to 3 weeks. Will have to change or modify bandages for these birds often as they outgrow them very quickly (sometimes as often as twice per week)

VI. Anesthesia
 A. Recommended fasting times
 1. Birds weighing less than 100 g are fasted for approximately 1 to 2 hours
 2. Birds weighing 300 g are fasted for 3 to 4 hours
 3. Birds weighing 600 g or more are fasted for 6 hours
 B. Avoid cuffed endotracheal tubes. Birds have complete tracheal rings in their tracheas, which can result in tracheal necrosis if the cuff is inflated
 C. Monitor anesthetic depth by response to painful stimuli, muscle tone, palpebral reflex, and respiratory rate and depth
 D. Inhalant
 1. Mask induction. Be careful that the bird does not eat the mask during inducing
 2. Monitor closely. Any decrease in respiratory rate once the animal is asleep and "stable" necessitates an immediate decrease in anesthetic concentration
 3. Benefits include being able to turn off quickly, having control over respiration, and the ability to administer oxygen
 4. Isoflurane and sevoflurane are inhalants of choice. Halothane has been used, but isoflurane is faster and safer
 5. Use a nonrebreathing system for birds under 10 kg
 E. Injectable
 1. Used more commonly in ratites
 2. Benefits: Minimizes handling time and consequently risk to handler
 3. Aspiration can be a problem when bird is sedated but cannot keep head up; will still fight restraint

VII. Drugs: Beyond the scope of this discussion to cover everything
 A. *Do not* use steroid preparations in birds except under dire circumstances of head trauma or shock
 B. In pet birds, exercise caution when using drugs with a gram-positive spectrum because most of a psittacine bird's normal gut flora is composed of gram-positive organisms
 C. Budgies: May have increased sensitivity to ivermectin

ORGAN SYSTEMS

I. Dermatology
 A. Anatomy of skin: Much thinner than in mammals
 1. Dermis contains feathers
 2. Bill or beak (rhampotheca): Contains Herbst corpuscles (mechanoreceptors used for food discrimination)
 3. Nails surround distal phalanx as in mammals
 4. Most birds have an uropygial gland (preen gland) found at the base of the tail, which has a purpose in waterproofing the feathers. Can become abscessed or develop neoplasia and require removal
 B. Feather formation, anatomy
 1. Contour feathers
 a. Primary flight feathers insert dorsally on the carpus and distally
 b. Secondary flight feathers insert along the ulna
 c. Tail feathers insert on the pogostyle
 2. Semiplume feathers: Fluffy feathers that enhance thermal insulation
 3. Filoplume feathers are associated with a Herbst corpuscle and are involved in providing sensory information
 4. Bristle feathers are found at base of eyelids, nares, and mouth and are involved in providing sensory information
 5. Down feathers contribute at least in part to maintaining body temperature
 6. Powder down feathers shed a powdery keratin, which assists in cleaning. Large numbers of these feathers account for the powder seen with cockatoos and African gray parrots
 C. Loss and replacement of feathers is referred to as molt. Growing feathers are called *blood feathers*
 D. Common problems
 1. Broken blood feathers
 a. Easiest way to stop a bleeding blood feather is to pluck the feather. The clot can then adhere to the skin of the feather follicle, and hemostasis occurs normally. When a new feather grows, some birds are prone to repetitive injuries of the same feather(s). Owners will often report that they think the bird has a broken wing
 b. There is usually a large amount of blood, and birds can suffer considerable blood loss, leading to hypovolemia and shock
 2. Feather picking or feather-destructive behaviors: Alteration of behavior with drugs or restraint devices may be necessary. Causes include the following:
 a. Behavioral (e.g., obsessive compulsive disorders, boredom). Diagnosis of exclusion,

rule out all other possible causes of feather picking first
b. Pain response from newly growing feathers or feather cysts
c. Aggression from other birds. Common during the breeding season and in finches
d. Poor skin condition: Lack of essential fatty acids in diet or environmental conditions (lack of humidity, etc.)
e. Skin infections (bacterial, fungal)
f. Hypersensitivity (very difficult to diagnose)
g. Parasites: Mites (common in psittacines) or lice (rare in psittacines)
h. Psittacine beak and feather diseas: See infectious section below

3. Feather cysts
a. Most common in canaries and often seen on wings. May see the feather curled around in the cyst. May be mistaken for fibrosarcoma or xanthoma
b. Can make a small incision and remove the feather material. Then cauterize the base of the follicle with silver nitrate. Alternatively, can surgically remove the offending feather follicle

4. Psittacine beak and feather disease: See infectious section below

5. Bumblefoot: Pododermatitis
a. Most commonly seen in captive raptors and overweight, sedentary psittacines
b. *Staphylococcus* species most frequently identified
c. Treat the infection and change lifestyle (e.g., weight loss)

6. Neoplasia
a. Lymphosarcoma most commonly reported
b. Xanthoma is a benign neoplasia seen commonly in budgerigars and cockatiels. Often require removal
c. Fibrosarcoma
d. Squamous cell carcinoma: Often in Amazons, though has also been seen in budgies and cockatiels

II. Skeletal system
A. Anatomy and physiology. Light bones with relatively thin cortices in flighted birds
1. Axial skeleton
a. Most of the vertebral bodies (except in the cervical region) are fused
b. Synsacrum is a fusion of the caudal thoracic, lumbar, sacral, and caudal vertebrae and is fused to the ilium
c. Pogostyle is the distal-most caudal vertebrae and supplies attachment for the tail feathers
d. Flighted birds have sternal ribs that are equivalent to the costal cartilage in mammals, and these provide more strength when pulled against by the flight muscles
e. Sternum (keel) is very large in flighted birds to provide an area of attachment for pectoral muscles. Reduced in nonflighted birds

2. Appendicular skeleton
a. Forelimb: Clavicles may fuse to form the furcula (wishbone). Ulna is larger and provides insertion for the secondary flight feathers. Primary flight feathers insert on the carpometacarpus. The allula (equivalent to the thumb) is important in steering during flight
b. Hindlimb: Femur is usually short and may be located within the body (loons, coots, penguins) and is pneumatic. Birds may have two (ostriches), three (emus), or four (passerines, psittacines, most other birds) digits. Birds with four digits: Digits 2, 3, and 4 forward (songbirds, hawks); digits 2 and 3 forward (psittacines); Digit 4 moveable between forward and rear facing (owls)

B. Problems
1. Fractures
a. Fractures of the humerus and femur may involve the respiratory system
b. Bones are lightweight with thin cortices; avoid iatrogenic fractures

2. Trauma
a. Often in young birds or those having severe feather trims
b. Often includes sternal wounds from having hit the ground on the sternum; results in the skin splitting off of the sternum. May suture, but there is usually a large amount of tension; recurrence is common
c. May also include tail injuries if the bird landed on its tail; usually consists of a horizontal tear to the skin of the ventral pogostyle. Often requires long-term bandaging
d. Birds are prone to getting their legs and wings caught between cage bars or in chains used to hang toys. A fracture may or may not be associated with the injury. If injury is acute, there is black or dark purple bruising, but if it is chronic, there may be green discoloration from the breakdown of heme to biliverdin

3. Hyperostosis and osteomyelosclerosis
a. A condition affecting female birds approximately 10 days before oviposition
b. Bird deposits extra calcium into the medullary cavity of the long bones to support egg production
c. May look as an almost solid medullary cavity or have a moth-eaten appearance on radiographs

4. Splay leg-crooked leg syndrome
a. Caused by an interplay of many factors including trauma, poor footing, genetics, nutrition, lack of exercise, excess vitamins A or D, deficiency of calcium
b. Treatment may include specialized footing, changing diet, nutritional supplements, hobbles, bandages or any combination of these

III. Respiratory system
 A. Anatomy and physiology of respiratory system
 1. Cere: The area around the nostrils. In male budgies, the cere is usually blue; in female and juvenile budgies, the cere is usually tan to pink. Color changes may indicate gonadal tumors
 2. Nostrils: Should be clean and clear with no discharge
 3. Infraorbital sinus
 4. Trachea has complete tracheal rings. Bifurcation contains the syrinx (sound production)
 5. Lungs are paired and attached firmly to the ribs and dorsal body wall. Secondary bronchi terminate at the air sacs to form functional units of parabronchi
 6. Air sacs: Most birds have nine air sacs
 7. Birds lack a diaphragm. Inhale usually by lowering the sternum thereby enlarging the air sacs and resulting in an influx of air. Exhale by contracting the muscles of the ribs and sternum
 8. Birds transfer more oxygen during each breath cycle than mammals do
 B. Common physical examination or history findings
 1. Tail bob: Rhythmic up-and-down movement of the tail with each breath; increased respiratory effort
 a. Respiratory in origin from pneumonia or air sacculitis
 b. Nonrespiratory in origin as a result of abdominal mass compressing respiratory system or egg retention causing abdominal mass effect
 2. Tachypnea: Increased respiratory rate can be difficult to assess
 3. Voice change: Infection or inflammation of the syrinx (most common), trachea, or larynx
 4. Coughing: Uncommon in birds and nonspecific as in mammals
 5. Nasal discharge and sneezing
 a. Birds commonly sneeze several times daily. Sneezing without nasal discharge is often due to irritants or a dry environment
 b. Nasal discharge: Causes include accumulations of dead cells, dust, and debris in nostrils (seen in birds on marginal diets, in dry environments, or in birds with no access to bathing); foreign body; squamous metaplasia from hypovitaminosis A; or rhinitis. Mild rhinitis is treated with topical antibiotics or antifungals; severe rhinitis may require flushing, vitamin injections, and systemic antibiotics
 6. Periorbital swelling: Often conditions involving the infraorbital sinus. Causes include sinusitis (bacterial or fungal), granuloma often associated with hypovitaminosis A, trauma, orbital mass, abscess, or neoplasia
 7. Tracheal disease from *Aspergillus*, bacteria, or tracheal foreign body. Treat by placing an air sac breathing cannula to allow delivery of oxygen or anesthetic (or both) while retrieving the foreign body with an endoscope
 8. Pneumonia-air sacculitis from *Aspergillus*, bacteria, abscess, neoplasia, or foreign body (uncommon)
 9. Air sac rupture: Trauma is usually suspected
 10. Aspiration pneumonia: Most commonly associated with baby birds or convalescing birds that have been given materials (nutritional support) via a gavage tube into the trachea instead of esophagus. Abscess formation is common
 C. Specific disease conditions
 1. Teflon or other inhaled toxins (fumes from burning nonstick cookware, ovens in self-cleaning mode, burning butter or oils, candles, or air fresheners)
 a. Often sudden death with no noticed premonitory signs. May show regurgitation, dyspnea, and ataxia before death
 b. Diffuse pulmonary congestion and edema on necropsy
 c. Supportive care includes one dose of fast-acting steroid and oxygen therapy
 2. Aspergillosis: See infectious section below
 3. Avian tuberculosis: See infectious section below
 4. Respiratory system neoplasia is rare in birds
 5. Hypovitaminosis A can predispose to infections or granuloma formation
 a. Results in squamous metaplasia; common in birds on seed-based diets
 b. Can result in metaplasia of the salivary gland, leading to occlusion of the ducts causing cyst or abcess. Also causes blunting of the choanal papillae

IV. Gastrointestinal (GI) system
 A. Anatomy and physiology of the system
 1. Mouth
 a. The lack of a soft palate and incomplete hard palate results in the choanal slit
 b. Tongue is quite varied, depending on species and diet
 c. Salivary glands mostly secrete mucus to facilitate swallowing, but there is a small amount of amylase excreted
 2. Esophagus: May have an outpouching known as the *crop* for food storage. Absent in penguins and owls, fusiform in most raptors, and very large in pigeons to produce crop milk for feeding young
 3. Proventriculus: True glandular part of the stomach
 4. Ventriculus: Grinding part of the stomach; lined with koilin for protection
 5. Intestine: Short in species that eat fruit, meat, and insects; long in species that eat fish and grains. Most birds cannot digest lactose
 6. Cloaca: The terminal receptacle for the digestive, urinary, and reproductive tracts. Has three parts:
 a. Coprodeum is the continuation of the GI tract
 b. Urodeum contains the opening of the ureters and the reproductive tracts

c. Proctodeum is the smallest compartment closest to the vent. It contains the bursa of fabricius (site of B-lymphocyte production and maturation)
7. Liver
8. Pancreas

B. Common problems
1. Liver disease: Commonly see "lime green" urates in liver disease
a. Fatty liver disease: Causes include high-fat (seed) diets with restriction of exercise, deficiencies of biotin or methionine, or aflatoxin. Common in budgies, cockatiels, and Amazons; requires aggressive supportive treatment
b. Hepatotoxins include mycotoxins, heavy metals, drugs, for example. Multiple factors predispose to severe damage. Fibrosis or cirrhosis may occur
c. Hepatitis due to *Mycobacterium* organisms, chlamydophila, Pacheco disease, polyomavirus, or fungal infections (*Aspergillus*)
d. Neoplasia: May be primary (cholangiocarcinoma, hepatoma, hemangioma, lymphoma) or secondary (lymphoma, hemangiosarcoma)
2. Trauma
a. To beak or mouth (electrical burns, tongue lacerations, beak avulsion)
b. Crop injuries are usually secondary to improper hand feeding of neonates. Let heal and allow scab to fall off before closing
c. Foreign body (bird equivalent of "hardware disease")
3. Crop stasis
a. Lack of normal crop motility
b. Can occur in adults or young birds
c. Causes include crop burns, substrate ingestion, bacterial overgrowth, candidiasis, viral disease, systemic disease, lead poisoning, proventricular dilatation disease, or goiter
4. Regurgitation. Causes include behavioral (i.e., courtship behavior), overstretching of crop, dietary indiscretion (large amounts eaten in a short period without water), goiter, food allergies, proventricular dilatation disease, lead poisoning, GI obstruction, or metabolic disease
5. Chlamydophila: Often results in diarrhea; can also cause respiratory and liver disease
6. Proventricular dilatation disease: Signs include regurgitation, weight loss, and weakness
7. Diarrhea: Many possible causes
a. Excitement
b. Dietary indiscretion (rapid changes, large amounts of fruit, dairy products, toxic plants)
c. Bacterial disease is usually gram negative, with *Clostridium* a common secondary pathogen. Malnutrition, stress, and other diseases (polyomavirus, candidiasis, lead toxicity, proventricular dilatation disease, Pacheco disease, protozoal disease) predispose to bacterial disease
8. Candidiasis (*Candida albicans*)
a. Forms plaques in mouth, crop, esophagus, or rest of GI tract. May see general depression or regurgitation
b. Causes: GI upset of another cause, prolonged antibiotic therapy, diets high in carbohydrates or sugars
c. Look for budding yeast on Gram stain. Realize that birds eating a large amount of bread products will normally have budding yeast in their feces
d. Nystatin commonly used as a treatment but must come into contact with the organisms. During long-term antibiotic therapy, consider prophylactic treatment with antifungals
9. Cloacal prolapse
a. Most commonly seen in cockatoos, although any bird can be affected
b. Multifactorial and may include hormonal influences, infectious, inflammatory
c. May have prolapse of part or the entire cloaca. May also have prolapse of part of the reproductive or GI tract
10. Neoplasia
a. GI system neoplasia is not common; signs depend on location
b. Adenocarcinomas are described; papillomas are most common mass of the cloaca. Lymphoma also occurs in the cloaca

V. Urinary system
A. Anatomy and physiology of the system
1. Kidneys
a. Kidneys are fixed to the ventral fossa of the synsacrum
b. Cortical portion produces the urates; the medullary portion produces urine that is much less concentrated than the urine of mammals. The excretion of urates is a mechanism to conserve water. Nitrogen is excreted as uric acid
c. Renal portal valve is present in the common iliac vein. Drugs given in the caudal part of the body may be metabolized by the kidneys before reaching the systemic circulation
2. Ureter: Opens into the dorsal wall of the urodeum
3. Cloaca
4. Vent (the external opening)
5. Avian kidneys cannot concentrate other electrolytes much above the normal blood levels. Birds with a high salt intake (such as seabirds) rely on nasal salt glands to help control electrolyte levels

B. Common problems
1. Gout is a precipitation of uric acid
a. Clinical sign of severe renal dysfunction
b. Causes include obstruction of ureter; hereditary, excessive calcium; excess vitamins A, B, or D; excess protein in diet; or dehydration
c. Articular: Deposition in joints. Diagnosed on cytology of joint exudate

d. Visceral: Deposition on serosa of organs. Diagnosed on necropsy

2. Renal disease or failure
 a. Clinical signs include lethargy, weakness, anorexia, abdominal distention (from ascites or enlarged kidneys), gout, and lameness. Dehydration is often a contributing factor
 b. Diagnosis is usually made late in the course of disease. Plasma uric acid may increase, but this is not always reliable
 c. Treatment includes fluid therapy, nonnephrotoxic antibiotics, and allopurinol (if hyperuric). Low-protein diet may help
3. Neoplasia
 a. Common in budgerigars; seen in multiple species of wild and pet birds
 b. Clinical signs include pain, changes in use of leg, abdominal distention, increased respiratory effort
 c. Diagnosis often requires use of multiple modalities (radiographs, endoscopy). Ultrasound is not generally helpful. Blood work may be normal until disease is advanced

VI. Cardiovascular system
 A. Anatomy and physiology
 1. Large heart with four chambers
 2. Large amount of cardiac output goes directly to the legs for heat dispersal; with large stroke volumes, the heart can beat relatively slowly at rest
 B. Disease is not often found clinically. Murmurs are difficult to hear because of the high heart rate, and dyspneic birds are minimally handled. Pulse deficits are difficult to find because of the fast heart rate. Testing includes radiographs, electrocardiography, and echocardiography

VII. Endocrine system: Very similar to mammals (see Chapter 15, Endocrine Disorders)
 A. Unique anatomy and physiology
 1. Prolactin: Stimulates the production of crop milk in pigeons as well as stimulating broodiness and nesting behaviors
 2. Arginine vasotocin controls oviductal contraction during oviposition
 3. Mesotocin (unknown role)
 4. Thyroid glands: Dark red, oval paired glands just cranial to thoracic inlet. Effects of dietary deficiencies are more exaggerated in birds (goiter). Hypothyroidism and hyperthyroidism can occur
 5. Parathyroid glands: Two pairs of small yellow organs just caudal to thyroids. Hyperostosis-osteomyelosclerosis begins 10 days before laying and is induced by estrogens
 6. Pancreas: Lies between two limbs of duodenum. May see pancreatic atrophy of viral cause or pancreatitis secondary to chlamydophilosis, Pacheco disease, or polyoma-virus
 B. Problems of the endocrine system
 1. Diabetes mellitus
 a. Clinical signs include polyuria, polydipsia, glucosuria, and weight loss in the face of increased appetite (sometimes extreme)
 b. Diagnosis based on clinical signs with persistent glucosuria and elevated fasting serum glucose. Normal glucose in birds ranges from 250 to 500 mg/dL, but birds can have extreme stress hyperglycemia
 c. Test urine for glucose (birds have to be polyuric to get enough urine to test). Fecal contamination may result in elevated glucose readings. Serum insulin can also be measured
 d. Treat insulin-dependent diabetes with insulin, and recommend a high-fiber diet
 e. Transient diabetes mellitus may occur secondary to other disease conditions and can resolve with treatment of underlying disease
 2. Hypothyroidism
 a. Clinical signs may include poor feathering, skin disorders, nonpruritic feather loss, and obesity. Euthyroid sick syndrome exists in birds as it does in mammals
 b. Diagnosis requires presence of clinical signs *and* failure to respond to thyroid-stimulating hormone (TSH)-stimulation tests
 3. Goiter
 a. Most common in budgerigars and is associated with a deficiency of iodine in seed-based diets. The lack of iodine causes production of thyroxine to decrease, resulting in elevated TSH, with proliferation of thyroid
 b. Clinical signs are due to the space occupying lesion (e.g., dyspnea, regurgitation). Diagnosis based on history and signs
 c. Treatment is to provide oral supplementation or feed a non-iodine–deficient diet (formulated pellets)
 4. Clinical adrenal disorders are not seen in birds, although necropsy findings do support adrenal disease

VIII. Reproductive system
 A. Anatomy and physiology of male reproductive system
 1. Testes: Paired organs located near the cranial pole of the kidney; change in color, size, and texture based on reproductive season
 2. Epididymis
 3. Ductus deferens: In passerines, the termination of the ductus elongates during the immediate prebreeding season into a ball of tissue called the *cloacal promontory*. This is projected into the cloaca during breeding and can be used to sex the bird during the appropriate time of year
 4. Birds have no accessory sex glands
 5. Phallus: May be protrusible (e.g., in ducks, ostriches), nonprotrusible (e.g., in domestic fowl), or nonexistent (e.g., in psittacines and passerines)
 B. Anatomy of female reproductive system
 1. Usually only the left ovary and oviduct develop. Raptors often retain the right ovary and infrequently retain the right oviduct

2. Arterial supply to the ovary is via short branches of the cranial renal artery (this makes ovariectomy very difficult)
3. Ovary located just caudal to the left adrenal gland
4. Oviduct functionally divided into five parts:
 a. Infundibulum: Draws ovulated ovum into oviduct and produces chalaza (fibrous bands that suspend the yolk within the egg). Sperm host glands store sperm for fertilization at the appropriate time
 b. Magnum: Adds most of the albumin
 c. Isthmus: Adds the shell membranes and a small amount of albumin
 d. Shell gland (uterus): The narrow region adds a large amount of water, and the sac-like portion calcifies the egg. The egg remains in this location for an extended period
 e. Vagina
 (1) At junction of vagina and uterus are sperm host glands in some species

C. Physiology of reproductive system
1. Birds start to nest when the rainy season starts (in environments where the climate does not change). Adults molt when young leave the nest. In environments with distinct seasons, birds start to nest when the day length increases. When day length decreases, the birds will start their molt. In temperate zones, the cycles of breeding are controlled by day length. Longer days stimulate gonadal development. The pineal gland is responsible for photosensitivity
2. It is relatively easy to fool the hormonal system and bring that bird into breeding or an early molt by altering the day length

D. Common problems and procedures in males
1. Testicular tumors: Common in budgies; first sign may be paresis or paralysis of one leg. Sertoli cell tumors result in feminization
2. Orchitis: May only see infertility
3. Phallic prolapse (in species with protrusible phallus) is caused by trauma, infection, or weather fluctuations. May require amputation
4. Cloacal prolapse syndrome (cockatoos of both sexes)
 a. Generally occurs in birds that are very tightly bonded to at least one person and were typically hand-raised
 b. The begging activities that these birds display results in straining and dilation of the vent and will show displaced sexual attraction or behaviors. Humans perpetuate the problem by stroking the back or tail, cuddling the bird, or hand feeding softened foods
 c. Without appropriate behavior modification (of pet and owner), resolution is unlikely
 d. Cloacopexy often attempted to prevent prolapse, but with continued straining, the pexy eventually fails
5. Castration: Not often done because of increased mortality rates except as treatment for testicular neoplasia

E. Common problem and procedures in females
1. Egg binding, dystocia
 a. *Egg binding* is failure of normal egg transit through the oviduct. *Dystocia* is the mechanical obstruction to oviposition because of the egg's presence in the distal oviduct
 b. Causes include anatomic abnormalities, hypocalcemia, oviductal infection or fatigue, nutritional deficiencies or excesses
 c. Diagnosis is based on clinical signs, examination, and testing
 d. Stabilize the patient with fluid therapy, calcium, and heat. Surgical removal of the egg might be less traumatic that manual delivery
2. Egg-yolk peritonitis: Results from the presence of yolk material within the ceolomic cavity and usually has a poor prognosis
3. Chronic egg laying: Laying of a larger than normal clutch or multiple clutches regardless of the presence of a mate or the season
 a. Commonly seen in budgies, cockatiels, and lovebirds and often results in nutritional deficiency in hen (especially calcium). May be due to imprinting on humans and genetics
 b. Treatment includes improving diet, not removing eggs, decreasing the photoperiod to less than 10 hours daily, disturbing the environment, or hormonal modification (leuprolide)
4. Cloacal prolapse syndrome (cockatoos of both sexes)
5. Ovariectomy is rarely done but may be performed in severe cases of chronic egg laying or with ovarian neoplasia

IX. Infectious

A. Macrorhabdosis (*Macrorhabdus ornithogaster*). Also know as avian gastric yeast
1. Budgies seem to be the most widely affected species with two apparent disease processes. Other species commonly affected include parrotlets, lovebirds, canaries, and finches
 a. In acute disease, apparently healthy birds begin to regurgitate, lose weight, become anorexic, and may die within a few days
 b. In chronic disease, birds remain hungry and appear to eat a large amount but do not actually consume the food. Regurgitation is common, and undigested food may pass into the feces. Diarrhea may also be seen. There is a prolonged period of weight loss, and they eventually die
2. No definitive way to diagnose
3. Treat with high doses of amphotericin B by gavage twice daily for 30 days
4. Postmortem examination usually finds emaciation and may show ulceration and sometimes perforation of the GI tract

B. Polyoma
 1. Disease caused by a deoxyribonucleic acid (DNA) virus that can apparently infect all psittacine species and possibly some other species
 2. Most infections are subclinical, and the disease severity and length of virus particle shedding depends on the species in question
 3. Budgerigars
 a. Infections in nestlings occur within a few days of hatching
 b. Inhalation of virus is a main source of infection. Incubation period is very short
 c. Virus is shed in the droppings and in feather and skin dander
 d. Inapparently infected birds and those that survive infection shed disease until at least 6 months of age, possibly much longer
 e. Once breeding starts, virus levels in the tissues diminish and shedding may stop completely
 4. Infections in nonbudgerigar species are also common
 a. All parrot species at all ages are susceptible, but most are subclinical
 b. Disease usually occurs in hand-raised nestlings (hatch to 4 to 6 weeks old) and is spread by inhaling virus. Most birds shed virus for several weeks, but a small percentage of birds will shed lifelong
 5. Diagnosis of disease requires consistent histology findings. Polymerase chain reaction (PCR) of blood and cloacal swab can be used to detect virus shedding
 6. Control disease by using very strict quarantine and visitation protocols (relatively easily spread by fomites). Lovebirds, cockatiels, and budgies should not be kept on the same premises as larger, more valuable birds
 7. Vaccination is given every 2 to 3 weeks beginning at 6 weeks of age. It is not protective until 2 weeks after the second vaccination. Most chicks are already infected by this age, so it is questionable whether vaccination is efficacious
 8. Key to control is to stop bringing baby birds into the affected nursery and stop any possible transmission of the virus out

C. Pacheco disease
 1. Almost exclusive to psittacines
 2. Caused by a herpesvirus, which is shed in feces and oral, nasal, and ocular secretions. Incubation period is usually 5 to 14 days
 3. Birds that are infected but do not develop disease or are treated and recover are considered persistently infected. Subclinically infected birds probably do not shed large numbers of virus during nonstressed times, but during times of stress, shedding greatly increases and outbreaks may occur
 4. Most common clinical sign is an acutely dead bird, though may see nonspecific signs of lethargy, depression, and anorexia. Birds are usually in good body condition and may have eaten recently
 5. Definitive diagnosis requires PCR or oral and cloacal swabs as well as blood
 6. Vaccine is available but may not protect against all serotypes
 7. Control disease by not keeping conures in mixed collections because these birds have been implicated in many outbreaks. Test live birds with PCR (blood and cloacal swab) to attempt to identify carriers. Treatment is supportive (e.g., with acyclovir) and does not usually result in cure, but in a carrier state

D. Internal papillomatosis of parrots
 1. Caused by a herpesvirus (same as Pacheco disease)
 2. Primarily affects macaws, conures, hawk-headed parrots, and Amazons
 3. Often see papillomas on the mucosal surfaces of the oral cavity or cloaca
 4. Grossly, papillomas are pink or white with a broccoli-like appearance
 5. Clinical signs include visualization of the papilloma, straining to defecate, fecal staining of the tail, dyspnea, wheezing, and excessive salivation. Lesions often come and go; asymptomatic periods may be lengthy
 6. Bile duct carcinoma and pancreatic duct carcinoma are commonly associated with internal papillomatosis
 7. Diagnosis is made by observing the lesions in the oral cavity or in the cloaca and biopsy (other locations possible, but difficult to see lesions)
 8. Treatment usually involves surgical removal

E. Psittacine beak and feather disease (PBFD)
 1. Historically most common in cockatoos, lovebirds, budgies, Eclectus parrots, and African gray parrots
 2. Usually seen in birds between 6 months and 3 years of age, although much older at first presentation is possible (incubation periods may be as short as 3 weeks or as long as several years). May live for many years with disease but most eventually die of the disease or secondary infections
 3. Clinical signs may include a lack of powder on beak, delayed molt, abnormal feathers, or hyperkeratosis of the feather sheath. Cockatoos may show beak abnormalities, including elongation, development of longitudinal fissures, and fracture of the tip of the beak. Nestling cockatoos may be affected by acute form of disease, which results in depression, regurgitation, and feather lesions. Most infections with clinical signs are fatal
 4. Transmission via inhalation of virus. The virus can also be passed to young via crop contents
 5. Birds with PBFD may have severe derangements of immune function, making them more susceptible to opportunistic pathogens
 6. Diagnose based on a PCR for the viral DNA. All clinically normal birds with a positive PCR should be isolated and retested in 3 months

7. Should test all new birds at the time of purchase and again 1 month later (assuming the PBFD is not already in the flock to which the birds are added)
8. No vaccine currently available in United States

F. *Salmonella*
1. Clinical signs may vary from mild enteritis to severe illness, including anorexia, lethargy, diarrhea, dehydration, and GI stasis; acute death may occur. Subacute disease may present with central nervous system (CNS) signs; dyspnea; and liver, spleen, or kidney damage. Carriers can develop infection, and eliminating infection is difficult
2. Diagnose by demonstrating organism on fecal culture. Postmortem may see muscle degeneration, splenomegaly, hepatomegaly, air sacculitis, nephropathy, and gastroenteritis
3. Treat with appropriate antibiotics long term, clean environment, and cull carrier animals
4. Not usually zoonotic unless person is immunocompromised (young, elderly, etc.). Humans can also pass disease back to birds (usually large psittacines)

G. Chlamydiosis and chlamydophilosis
1. Caused by *Chlamydophila psittaci*, an obligate intracellular bacterium that can infect birds, reptiles, and mammals, including humans, where it causes flu-like symptoms. Budgies and cockatiels are more commonly infected than other birds
2. Elementary bodies are small particles that can exist outside the host and are infective. These are shed in feces, urine, saliva, and respiratory exudates; then they are ingested or inhaled by the bird and enter the epithelial cells. Elementary bodies are unstable if exposed to heat or sunlight but can remain infective for months in fecal material. Latent, persistent infections are common
3. Clinical signs include depression; weight loss; unthriftiness; rhinitis; dyspnea; and liver, kidney, or GI involvement. Asymptomatic carriers may develop clinical signs during stressful episodes
4. Birds showing clinical signs are shedding the organism and can be diagnosed by immunofluorescent assay, culture, or titers. Difficult to diagnose subclinically infected birds because they are not shedding the organism. To screen large avian facilities can do pooled fecal samples
5. Must disinfect entire aviary when a positive bird is found. All birds sharing the air space of the infected bird must be considered exposed
6. Requires prolonged (45 days or longer) treatment with antibiotics (tetracyclines) to cure disease, and there is very short-lived immunity after clearance of the infection
7. Chlamydophilosis is a reportable disease. Birds being brought into the country are quarantined for 45 days and put on tetracyclines

H. Proventricular dilatation disease (macaw wasting disease)
1. Thought to be caused by a virus or virus complex. Affected birds may be 2 months to several years old at time of diagnosis, and all groups of psittacines are considered at risk
2. Generally an acute disease characterized by depression, weight loss, regurgitation, and passage of whole seeds in the feces. Birds will often continue to eat normally but still lose weight. May also see CNS signs, which may or may not be progressive. Specific signs are related to which nerves are affected and can be quite varied
3. Radiographically, the proventriculus or ventriculus may be dilated
4. Definitive diagnosis is made with histopathology on samples either taken at necropsy or on biopsy of the crop or ventriculus (crop easier but ventriculus more likely to have lesions). Histologically see lymphoplasmacytic infiltration of the affected nerves. Positive is truly positive, but negative is not necessarily negative
5. There is no cure, although treatment with nonsteroidal anti inflammatory drugs (e.g., Metacam, Celebrex) may alleviate signs
6. Prognosis is poor, many birds die shortly after diagnosis
7. Birds should be quarantined for 6 months or longer, and birds should not be parent raised

I. Aspergillosis
1. Transmitted by inhalation. Largely opportunistic with infection occurring only when the animal is stressed or immunosuppressed
2. Lesions are most often seen first in air sacs and airways (especially the syrinx)
3. Clinical signs include dyspnea, voice change (if granulomas develop in the syrinx), exercise intolerance, and nonspecific signs such as weight loss, inappetence, diarrhea, depression, and lethargy
4. Diagnosis can be difficult but is suspected based on history, elevated white blood cell counts (WBC), and elevations in globulin levels. Radiographic changes may or may not be visible. Endoscopy is the easiest mode of diagnosis
5. Treat by debulking the granuloma, the treating with antifungals (amphotericin B, flucytosine, ketoconazole, or itraconazole). May require supportive care and antibiotics for secondary infections. Prognosis is poor
6. Prevent by decreasing predisposing factors and assuring a clean, nondamp environment that does not facilitate the growth of *Aspergillus*

J. Avian tuberculosis (*Mycobacterium avium*)
1. Transmission is through ingestion or inhalation of feces. *M. avium* is very stable in the environment
2. Clinical signs may include chronic wasting, depression, diarrhea, poor feathering, abdominal distention, SC masses, or acute death.

May see tubercles in liver, spleen, GI tract, and lungs. The atypical form (no tubercles) is difficult to diagnose
3. Diagnose by finding acid-fast rod-shaped organisms in feces or in smears or sections of lesions taken by biopsy or at necropsy. Culture is difficult, but DNA probes and PCR tests are available
4. Treatment requires long-term therapy, but some will recommend euthanasia because of the risk to humans (especially those who are immunosuppressed)
5. Exposed birds should be isolated long term (years)

K. West Nile virus (flavivirus)
1. Birds are the primary vertebrate host, with mosquitoes as vector
2. After infection, a bird remains viremic for 4 to 7 days, and the degree of viremia depends on the bird species. Crows, magpies, and other corvids develop the highest degree of viremia; corvids, accipiters, red-tailed hawks, and some owls are most commonly afflicted with disease
3. Close contact or sharing of saliva or feces may result in infection
4. Clinical signs may include sudden death or CNS signs. Some believe a small number of infected animals do recover. Antibodies can usually be detected within 14 days of infection and are used to diagnose disease
5. There is no avian-approved vaccine at this time

X. Toxicology: Most common clinical presentations
A. Lead intoxication
1. Most common sources include-lead based paint, costume jewelry, lead weights used for curtains or fishing sinkers, solder from home-made cages, batteries, toys, stained glass, and other such objects
2. Wild birds are commonly affected by lead poisoning by ingesting lead shot or ingesting animals with subclinical lead poisoning (large raptors, such as eagles are often most severely affected as the compound bioaccumulates in these animals)
3. Common signs include anemia; nervous system disorders, including weakness, paresis, and localized or diffuse paralysis; GI signs; and renal signs
4. Diagnosis is made by an increased suspicion based on history and clinical signs, visualization of metallic densities on radiographs, and testing of whole blood
5. Treatment includes removal of lead particles when found (either by flushing out of the GI tract with high-fiber diets or removal via surgery or endoscopy), and chelation therapy with succimer or calcium ethylenediaminetetraacetic acid (EDTA)
a. Calcium EDTA is considered the better initial chelator, but it is recommended that animals be given fluids to protect the kidneys
b. Succimer seems to have a relatively narrow range of safety

B. Zinc intoxication
1. Sources include hardware cloth in homemade cages, screws, nuts, bolts, U.S. pennies made after 1983, and the clappers of bells (in cheaper bird toys)
2. Clinical signs can include polyuria, polydipsia, weakness, anemia, feather picking (in low-exposure, chronic toxicosis), seizures, and acute death. Some may have an increased WBC
3. For testing, serum should be collected and quickly put into blood tubes without rubber stoppers. Some recommend drawing blood with syringes without rubber plungers, but the need to do this is not universally agreed upon
4. Treatment consists of removing zinc from the GI tract or by flushing the material through the tract (e.g., psyllium, peanut butter, mineral oil). Often removal of the material is timely enough to prevent the need for chelation. If needed, chelation therapy may consist of calcium EDTA, D-penicillamine, or succimer. Chelation therapy must be undertaken with or after the removal of the substance from the GI tract

C. Inhalant
1. Most commonly indicated is Teflon (polytetrafluoroethylene, PTFE), although any strong odor or smoke from any source can be toxic
2. Clinical signs often consist of acute death, though dyspnea, ataxia, depression, or agitated behaviors can all be seen. Often there is hemorrhage or edema of the respiratory tract results in death
3. Prognosis is guarded or poor if the animal is found before death
4. Treatment includes steroids, diuretics, analgesia, and oxygen

D. Other toxins include nicotine, caffeine, chocolate, avocado, and various plants

XI. Behavior
A. Hatchling is a baby bird between hatching and the time the eyes open
B. Nestling is used to refer to a baby bird once the eyes open
C. Fledgling is used to refer to a baby bird at the time it learns to fly. Fledging occurs before weaning in the natural environment
D. Weanling is used to refer to the baby animal as it is learning to find and eat food unassisted
E. Young birds. Age at maturation in psittacines correlates with size of the bird
1. Cockatiels and budgies usually wean by 6 to 11 weeks old and are sexually mature at 4 to 6 months old
2. Medium-sized birds, such as African grays and Amazons, wean at 3 to 4 months old and reach sexual maturity at about 3 years old
3. Large birds like macaws wean at 4 to 5 months old but are not sexually mature until about 5 years old

F. The raising of birds in a typical breeder situation can lead to a number of problems, including inappropriate vocalizations, feather picking or destructive/self-mutilation behaviors, shyness,

aggression, obsessive compulsive disorders, phobias, and continued food-begging behaviors. These may result from not housing the babies appropriately for the age, inappropriate feeding behaviors, premature feather trims and prevention of normal fledging, and premature weaning

G. Sleep deprivation can result in birds that are hyperactive, scream excessively, and have feather-destructive behaviors. Birds should have a night cage that is in a room unoccupied by people at night (12 hours of sleep is necessary for most birds)

H. Commonly seen behavior problems
 1. Inappropriate bonding to owners
 a. Might be negative behaviors initiated toward a person the bird is not particularly fond of or might be perceived positive behaviors toward the bird's favorite person. This may progress to the bird viewing the owner as their mate
 2. Hormonal abnormalities are responsible for some behavior problems
 a. Captive birds reach puberty earlier than wild birds (sometimes several years earlier)
 b. Some birds also do not have a definitive reproductive cycle but remain hormonally active throughout the year
 c. Initiated in part by lack of seasonality, lack of scarcity of food, lack of change in photoperiod, as well as inappropriate mate bonding with humans
 d. Some birds (Amazons, cockatoos) can become very aggressive during breeding seasons, and this can result in aggression in these birds
 e. Treatment by hormone manipulation alone may be successful in some cases, but others require changes in the environment to control the hormonal deluge these birds experience
 3. Screaming behaviors
 a. Birds are vocal animals and will have bursts of vocalizing several times daily that are normal and should be expected. Excessive vocalization is usually aimed at achieving some goal
 b. Birds may normally vocalize when feeding and when greeting owners when they arrive home. If ignored, screaming may ensue
 4. Biting behaviors: Most often are fear based or territorially based
 a. Fear biting may be overcome with gradual desensitization
 b. Territorially-based biting is the result of the bird defending what it sees as its territory and requires training to overcome
 5. Feather destruction and self-mutilation
 a. Most common in African grays and cockatoos. Not seen in wild birds
 b. Causes include behavior, nutritional (excesses, deficiencies, allergies), environmental (lack of humidity, contaminants), dermatologic factors, toxicities, hormonal influences, metabolic disease. The cause is rarely found
 c. Behavior-modifying drugs are often tried but rarely completely successful

Supplemental Reading

Altman RB, Clubb SL, Dorrestein GM, Quesenberry K. *Avian Medicine and Surgery.* Philadelphia, 1997, Saunders.

Fudge AM, editor. *Laboratory Medicine, Avian and Exotic Pets.* Philadelphia, 2000, Saunders.

Harrison GJ, Lightfoot TL. *Clinical Avian Medicine.* Palm Beach, FL, 2006, Spix Publishing.

O'Malle B. *Clinical Anatomy and Physiology of Exotic Species*. Philadelphia, 2005, Saunders.

Rupley AE. *Manual of Avian Practice*. Philadelphia, 1997, Saunders.

Samour J, editor. *Avian Medicine*. Philadelphia, 2003, Mosby.

Tully TN, Dorrestein GM, Lawton M. *Handbook of Avian Medicine.* Boston, 2000, Butterworth-Heinemann.

55 CHAPTER

Ferrets

Patricia A. Schenck

RESTRAINT

I. Often only minimal restraint is needed
II. Restrain by placing a hand under the chest and lifting slightly
III. Scruffing can be used for restraint when the ferret is grasped by the skin on the back of the neck and lifted up (Figure 55-1)
IV. Ferrets can be restrained on a table by placing one hand over the back of the head and the other hand over the pelvis. Do not pull the legs back

DIAGNOSTIC AND THERAPEUTIC TECHNIQUES

I. Blood collection
 A. Sites for blood collection include the cephalic vein, lateral saphenous vein, jugular vein, cranial vena cava, and ventral tail artery
 B. Collect three times the amount of blood as the volume of serum or plasma required
 C. Use 28-gauge or 25-gauge needles for peripheral veins. Use 25-gauge or 22-gauge needles for jugular vein or cranial vena cava collection
 D. Blood collection from the ventral tail artery can be painful
II. Diagnostic imaging
 A. Standard radiographic techniques are used
 B. Sedation may be necessary
 C. Splenomegaly is common
III. Bone marrow aspiration
 A. Collect from the proximal femur or humerus
 B. Use sedation
IV. Splenic aspiration
 A. Do not perform if hemangiosarcoma is suspected
 B. Sedation is not usually necessary
V. Cystocentesis
 A. Use a 22-gauge or 25-gauge needle
 B. Sedation or anesthesia may be necessary
VI. Intravenous (IV) therapy
 A. Use the cephalic, lateral saphenous, or jugular veins for indwelling catheters
 B. A 25-gauge butterfly catheter can be used in the cephalic vein for one-time administration
VII. Injections
 A. Give subcutaneous (SC) injections over the shoulders
 B. Give intramuscular (IM) injections in the quadriceps, semimembranosus, semitendinosus, or epaxial muscles of the back
VIII. Fluid therapy
 A. Daily fluid requirement is approximately 70 to 100 mL/kg/day
 B. Give SC fluids over the shoulders
 C. Hypoglycemia is common; thus dextrose may be added to IV fluids
IX. Oral therapy. Liquid medications are the easiest to administer
X. Nutritional support
 A. Can be force-fed using a syringe
 B. Feed meat baby foods, slurried canned cat foods, or ferret food
XI. Drug-dosing guidelines
 A. No drugs are approved for ferrets
 B. Use feline dosages for most drugs
 C. Use ivermectin for heartworm prevention
 D. Enalapril may cause lethargy in ferrets
XII. Sedation and anesthesia
 A. Use acepromazine for sedation. A combination of acepromazine and ketamine can be used for minor procedures
 B. Do not use xylazine
 C. Telazol can also be used as a sedative
 D. Isoflurane by facemask is commonly used for induction

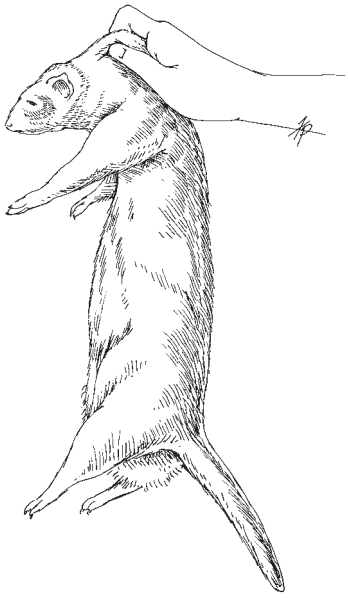


Figure 55-1 "Scruffing" a ferret for restraint. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

1. Give analgesics to relieve pain
2. Analgesics used include buprenorphene, butorphanol, carprofen, and flunixin

INFECTIOUS DISEASES

I. Viral diseases
 A. Canine distemper
 1. Paramyxovirus; transmission is via direct contact or fomites
 2. Clinical signs include conjunctivitis, fever, anorexia, mucopurulent oculonasal discharge, and central nervous system abnormalities
 3. Fatal; there is no treatment
 4. Vaccination is protective; vaccinate yearly
 5. Do not use canine multivaccines that contain parvovirus, adenovirus
 B. Influenza
 1. Orthomyxovirus; transmission to and from humans
 2. Clinical signs include conjunctivitis, nonproductive cough, diarrhea, anorexia, and fever
 3. Treat supportively
 C. Rabies
 1. Rhabdovirus; transmission is via direct contact with infected saliva
 2. No treatment
 3. Some states allow a 10-day quarantine of an unvaccinated ferret involved in a bite incident; some states require euthanasia
 4. Vaccinate with killed vaccine yearly
 D. Aleutian disease
 1. Parvovirus that also affects mink; transmission is via direct contact or fomites
 2. Clinical signs include ataxia, lack of coordination, posterior paresis, tremors, wasting, anorexia, lethargy, melena, and urinary incontinence
 3. Incubation period from 1 to 200 days
 4. Serum protein electrophoresis shows hypergammaglobulinemia
 5. An enzyme-linked immunosorbent assay (ELISA) test is available
 6. There is no specific treatment; provide supportive care and isolate
II. Bacterial diseases
 A. Common bacterial infections
 1. *Staphylococcus*, *Streptococcus*, *Escherichia coli,* and others can cause bacterial infection
 2. Abscesses are uncommon
 3. Treat according to bacterial sensitivity
 B. Botulism is rare but is caused by *Clostridium botulinum* toxin in uncooked food
 C. Tuberculosis
 1. Ferrets are susceptible to bovine, avian, and human tuberculosis
 2. Transmitted by ingesting contaminated meat or milk
 3. Clinical signs include weight loss and diarrhea
 4. Because tuberculosis is zoonotic, animals should be euthanized and not treated
III. Fungal infections
 A. Systemic fungal infections are rare
 B. Blastomycosis, histoplasmosis, cryptococcosis, coccidioidomycosis, and aspergillosis have been reported

HEMATOPOIETIC SYSTEM

I. Splenomegaly may be a normal or incidental finding
 A. Extramedullary hematopoiesis may cause enlargement; lymphoma is the most common tumor of the spleen
 B. Abdominal distention may occur
 C. Treat any underlying conditions
II. Anemia
 A. Anemias occur in ferrets as in other species
 B. Hyperestrogenism may cause a nonregenerative anemia
 C. Clinical signs, diagnosis, and treatment are similar to those of other species

NEOPLASIA

I. Insulinoma is a common tumor usually in ferrets older than 2 years
 A. Cause is unknown
 B. Clinical signs include hypersalivation, pawing at the mouth, lethargy, depression, "stargazing," stupor, seizures, or coma
 C. Diagnosis is usually based on a low serum glucose concentration. Insulin concentration is typically elevated
 D. The ferret has a large pancreas for its size. Surgery is recommended to debulk the tumor but is usually not curative, providing temporary remission
 E. Medical therapy can control symptoms
 1. Feed frequent high-quality protein, high-fat meals
 2. Corticosteroid therapy helps to increase hepatic gluconeogenesis
 3. Diazoxide can be added but is expensive and not palatable
II. Adrenal gland neoplasia is common
 A. Excessive sex steroids are produced (not excessive cortisol as in canine hyperadrenocorticism)
 B. Cause is unknown but may be related to early neutering
 C. Clinical signs include bilaterally symmetric alopecia, pruritus, dry skin, enlarged vulva in females, urinary obstruction (males), pendulous abdomen, atrophy of muscles, and polyuria-polydipsia (uncommon) (Figure 55-2)
 D. Elevated sex steroid concentrations occur (estradiol, androstenedione, 17-hydroxyprogesterone)
 E. Surgical removal of the adrenal gland is the treatment of choice
 F. Medical therapy includes the use of leuprolide or deslorelin. Mitotane is typically not effective
III. Lymphosarcoma is common in all ages of ferrets
 A. Lymphocytic lymphoma typically affects adults; lymphoblastic lymphoma affects young ferrets
 B. Cutaneous lymphoma may occur
 C. Clinical signs and diagnosis depend on the organs involved
 D. Lymph node biopsy is best for diagnosis. Bone marrow aspiration may be necessary



Figure 55-2 The typical pattern of hair loss in a ferret with an adrenocortical tumor. (From Quesenberry KE, Carpenter JW. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery*, 2nd ed. St Louis, 2004, Saunders.)

E. Perform splenectomy if the spleen is involved
F. If there is bone marrow involvement or solid tumors in organs, the prognosis is poor

IV. Skin tumors are the third most common neoplasia in ferrets
A. Mast cell tumors are typically benign. Metastasis is rare
B. Sebaceous epitheliomas are common

V. Other tumors can occur in the gastrointestinal (GI) tract, reproductive tract, and other sites

DERMATOLOGIC DISEASES

I. Seasonal changes in skin and hair coat
A. Thinning of the hair usually occurs in the spring, and the coat becomes darker. Ferrets may also lose up to 40% of their body weight at this time (this is normal)
B. Hair regrowth takes place in fall and winter
C. Shaved hair regrowth is typically slow. There is often a bluish discoloration of the skin during hair regrowth, which is normal

II. Infectious diseases
A. Bacterial infections are usually abscesses or diffuse pyoderma
B. Ulcerative pyoderma is commonly caused by *Staphylococcus* or *Streptococcus*
C. Canine distemper virus infection often causes skin lesions, typically around the lips, chin, eyes, and inguinal area
D. *Microsporum canis* and *Trichophyton mentagrophytes* may cause mycotic infection

III. External parasites
A. Fleas can infest ferrets
1. Do not use lindane or organophosphates
2. Pyrethrin can be used; additionally, imidacloprid, lufenuron, fipronil, and selamectin have been used
B. Ear mites (*Otodectes cyanotis*)
1. Excessive wax production can occlude the external ear canal
2. Pruritus is uncommon
C. Sarcoptic mange is transmissible between dogs and ferrets. Lesions are usually on the feet
D. Demodectic mange is rare

IV. Endocrine alopecia
A. Tail alopecia is seen at the time of the fall molt. No treatment is necessary
B. Estrus alopecia may be seen if the ferret has been in estrus for longer than 1 month
C. Hypothyroidism has not been documented

CARDIOVASCULAR DISEASES

I. Congestive heart failure (CHF)
A. Common in ferrets
B. Clinical signs include anorexia, ascites, coughing, dehydration, dyspnea, exercise intolerance, weakness, lethargy, and weight loss
C. Diagnose based on radiography, electrocardiography, and echocardiography findings
D. Treat with furosemide, angiotensin-converting enzyme (ACE inhibitors; e.g., enalapril)
E. Use digoxin in those with cardiomyopathy
F. Avoid feeding high-salt diets

II. Cardiomyopathy
A. Dilated cardiomyopathy is more common than the hypertrophic form
B. Treat as for CHF. Taurine supplementation is not effective

III. Heartworm disease
A. Clinical signs include coughing, dyspnea, hepatomegaly, anorexia, lethargy, weakness, and right-sided CHF
B. Microfilaria are present in about 50% of infected ferrets
C. Use an ELISA assay for *Dirofilaria* antigen
D. Treat with ivermectin, then melarsomine
E. Ivermectin can be used as a heartworm preventative

IV. Valvular heart disease
A. In ferrets older than 3 years
B. Treat as for CHF

V. Myocarditis
A. Secondary to underlying disorders
B. Treat the underlying disease

GASTROINTESTINAL SYSTEM

I. Nutrition
A. The ferret is an obligate carnivore
B. Nutritional requirements have not been determined, but the diet should contain predominantly animal protein and fat
C. Feed a high-protein, low-fiber diet because the ferret's GI tract is short
D. Premium cat foods can be fed, but do not feed dog foods

II. Dental disease
A. Tartar and periodontal disease are common
B. Moist diets may predispose

III. Nausea and vomiting
A. Nausea is recognized by hypersalivation and pawing at the mouth
B. Ferrets are able to vomit

IV. GI parasites are uncommon. Coccidiosis and giardiasis can occur
V. Gastritis and gastric ulcers are uncommon. Diagnosis is based on history and clinical signs
VI. Foreign bodies
 A. Hairballs are common
 B. Foreign bodies are usually rubber or foam
 C. Diagnose based on history, clinical signs, and radiography
 D. Surgical removal is the treatment of choice
 E. Prevent hairballs with a feline product
VII. Epizootic catarrhal enteritis
 A. Thought to be a coronavirus
 B. May cause mild diarrhea, severe diarrhea, or wasting disease
 C. Also known as *green slime disease*
 D. No specific treatment; treat supportively
VIII. Rotavirus
 A. Occurs in young kits (2 to 6 weeks old); also known as *ferret kit disease*
 B. Diarrhea with high mortality
IX. *Salmonella* is rare; associated with contaminated raw meat ingestion
X. Eosinophilic gastroenteritis
 A. Cause unknown; may be due to food allergy
 B. Chronic diarrhea and weight loss
 C. Change to a "hypoallergenic" diet. Treat with prednisone
XI. Inflammatory bowel disease
 A. Diarrhea, nausea, vomiting, and weight loss
 B. Young to middle-aged adults
 C. Corticosteroids or azathioprine can be used
 D. A "hypoallergenic" diet may be helpful
XII. Proliferative bowel disease
 A. Caused by *Lawsonia intracellularis*
 B. Young ferrets (4 to 14 months old)
 C. Diarrhea, painful defecation, lethargy, depression, weight loss, and fever
 D. Polymerase chain reaction and immunofluorescence antibody tests are available
 E. Chloramphenicol or metronidazole
XIII. Rectal prolapse is often associated with diarrhea. Replace surgically
XIV. Anal sac abscesses occur as in dogs and cats

REPRODUCTIVE SYSTEM

I. Normal
 A. Breeding season in March through August. Testicular size will be greater during breeding season
 B. Males (hobs) have a J-shaped os penis
 C. Females (jills) are induced ovulators
 D. Most females will remain in estrus if not bred. The elevation of serum estrogen results in bone marrow toxicity and pancytopenia. Ovariohysterectomy is recommended for all nonbreeding ferrets
II. Disorders in the female
 A. Pyometra
 1. Uncommon because most pet ferrets are spayed before purchase
 2. Clinical signs include vulvar discharge, lethargy, anorexia, and fever
 3. Perform ovariohysterectomy
 B. Vulvar swelling in spayed females
 1. Can be caused by an ovarian remnant or by adrenal gland disease
 2. Give human chorionic gonadotropin IM. If there is an ovarian remnant, the swelling will decrease. Remove the ovarian remnant
 C. Pregnancy toxemia
 1. Caused by lack of nutrition late in pregnancy
 2. Life-threatening; perform cesarean section, treat aggressively with dextrose-containing fluids and high-calorie diet
 3. Prognosis is poor
 D. Mastitis
 1. Abrasions to the mammary glands may result in mastitis
 2. Acute mastitis causes swollen painful mammary glands, typically immediately after whelping or during the third week of lactation. Treat acute mastitis aggressively
 3. Chronic mastitis results in scarred, nonfunctional mammary glands
 4. Do not breed any female with a history of mastitis

URINARY SYSTEM

I. Renal disease is not common. Clinical signs are similar to those in other species
 A. Proteinuria may be normal in ferrets
 B. The urinary bladder is very fragile and should be handled with caution
II. Renal cysts are common, and the cause is unknown
 A. Typically there are no clinical signs
 B. No treatment is necessary if asymptomatic
III. Urolithiasis has decreased in ferrets, most likely because of improvement in diet
 A. Stones are usually calcium oxalate or struvite and may cause urethral obstruction
 B. Vegetable protein or poor quality animal protein diets have been implicated in stone formation
IV. Prostatic disease is usually associated with adrenal gland disease, and may be related to excessive stimulation by androgens
 A. Adrenalectomy is the treatment of choice
 B. Leuprolide injection can also be used to shrink prostatic tissue
V. Paraurethral cysts occur on the dorsal side of the urinary bladder and urethra, and are associated with adrenal gland disease. The treatment of choice is surgical drainage and debulking of the cyst

Supplemental Reading

Ellis C. Ferrets. In Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders pp. 1816-1857.

Quesenberry KE, Carpenter JW, editors. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery,* 2nd ed. Philadelphia, 2004, Saunders.

56 CHAPTER

Rabbits

Patricia A. Schenck

BIOLOGICAL CHARACTERISTICS

I. Anatomy and Physiology
 A. Rabbits are lagamorphs, not rodents. Life span is about 5 to 9 years
 B. The dewlap under the chin is prominent in some breeds and is a frequent site of moist dermatitis
 C. Teeth grow continuously. Permanent teeth erupt around 3 to 5 weeks of age
 D. Rabbits have a simple stomach, a long intestinal tract, and a large cecum. The stomach is rarely empty, and the cecum holds about 40% of the gastrointestinal (GI) contents
 E. Cecotrophs are "night feces," which rabbits normally consume
 F. The skeletal system constitutes only about 8% of body weight compared with 13% of body weight in cats
 G. Urine may normally be thick and creamy in appearance because of calcium carbonate. Rabbits excrete most of their calcium and phosphorus through the urine. Urine is also periodically red, pink, or orange from porphyrin pigments
 H. Neutrophilia and lymphopenia are characteristic of inflammation

II. Reproductive characteristics
 A. Females (does) mature at about 4 to 8 months of age, and males (bucks) mature at about 6 to 10 months of age
 B. Females are induced ovulators. Mating can occur at any time of the year but is influenced by light and temperature. Gestation is about 30 to 33 days
 C. Litters usually range from 4 to 10 kits. Kits are born blind and hairless. Does usually only nurse once daily for 3 to 5 minutes
 D. Kits start eating solid food about day 15

MANAGEMENT

I. Caging
 A. Cages need to be large enough to allow movement, tall enough to allow the rabbit to stand on its hindlegs, and easy to clean
 B. Wire-mesh flooring may be used, but only if it is wide enough and with small enough openings to avoid sore hocks. If wire mesh is used, provide part of the cage with a solid bottom
 C. Stray or hay bedding should be provided and cleaned daily. Many rabbits can be trained to use a litterbox because they prefer to urinate and defecate in one spot
 D. Rabbits are susceptible to heat stroke at temperatures greater than 85° F. If rabbits are kept outdoors, provide good ventilation, protection from direct sunlight, and protection from flies
 E. Rabbits should be allowed time out of the cage for exercise, but only with supervision

II. Diet
 A. High-fiber diets are required for GI health and proper wearing of the teeth. Provide free-choice timothy or coastal hay. Alfalfa is high in calcium and should be used with caution
 B. A variety of vegetables and fresh, leafy greens should be offered several times daily
 C. Pelleted diets may be convenient, but most are alfalfa based, nutrient dense, and low in fiber
 D. A small amount of fruits (2 tbsp/2 lb body weight) can be offered daily
 E. Fresh water should always be available. Daily average water intake is 50 to 150 mL/kg

CLINICAL TECHNIQUES

I. Restraint
 A. Gentle, but firm restraint is important, as inadequate restraint can lead to hindleg kicking with fracture of the spine. Always support the hindquarters when lifting a rabbit (Figure 56-1)
 B. Carry a rabbit with its head tucked under one arm with the body resting on the forearm. Use the other hand to stabilize the dorsum of the back and rump

II. Diagnostic techniques
 A. Collect blood samples from jugular, cephalic, lateral saphenous, or lateral ear veins. Use a small-gauge needle (25 gauge). To prevent hematomas, apply direct pressure over the site for several minutes. The lateral saphenous vein is the best site for obtaining blood for routine blood tests. Pluck the hair to see the vein more clearly
 B. On radiographs, the stomach and cecum are often full of ingesta. Rabbits have small thoracic cavities
 C. Ultrasound is useful but requires sedation

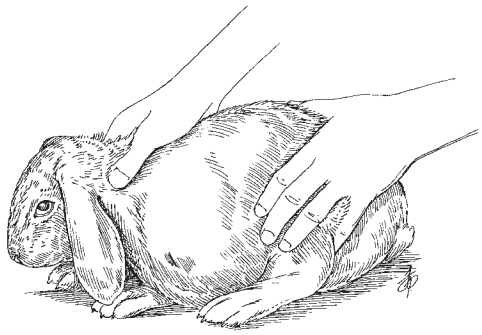


Figure 56-1 Proper method for restraining a rabbit. (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

III. Treatment techniques
 A. Small-gauge catheters (24 gauge) can be placed in the cephalic or lateral saphenous vein. Jugular catheters can be difficult to place. Daily maintenance fluid needs are 100 to 150 mL/kg/day
 B. Medications can be given orally into the lateral cheek pouch. Use liquid or paste preparations
 C. Anorectic animals can be fed via syringe either a special hand-feeding formula or rabbit pellets that are moistened and made into a gruel. Vegetable baby foods are low in protein and fiber and should be avoided. Nasogastric tubes can be placed
 D. Dietary *Lactobacillus* supplements may be useful in treating enteritis or when treating with antibiotics
IV. Tranquilization, anesthesia
 A. Injectable tranquilizers such as ketamine (5 to 10 mg/kg) and medetomidine (0.15 to 0.18 mg/kg) given in combination intramuscularly or intravenously provide relaxation and sedation
 B. Inhalant anesthesia
 1. Isoflurane or sevoflurane are used for longer procedures. Induction is via face mask or induction chamber. Premedicate with combination of ketamine and metetomidine, especially if using isoflurane. Monitor rabbits closely
 2. Intubation can be difficult. Repeated attempts to intubate can damage the larynx; consider using a facemask if intubation is difficult

DERMATOLOGIC PROBLEMS

I. Dermatitis, alopecia
 A. Causes
 1. Mange, fur, and ear mites
 2. Dermatophytosis, especially around head and ears
 3. Fur-barbering is common if diet is deficient in roughage
 4. Malocclusion can cause alopecia and dermatitis around the mouth (Figure 56-2)
 5. Moist dermatitis of the dewlap is common in warm, humid weather. Moist dermatitis of the ventral abdomen or perineum results from urine scald
 6. Treponematosis causes scaly dermatitis in the genital area
 B. Clinical signs are dependent on cause. Fur barbering is usually of the dewlap, back of neck, and paws; underlying skin is normal
 C. Diagnosis is by examination of skin scrapings, skin biopsy, teeth, radiographs, and serum biochemistry
 D. Treatment is aimed at correction of the underlying cause



Figure 56-2 Moist dermatitis under the chin of a rabbit secondary to drooling because of dental malocclusion. (Courtesy Elizabeth Hillyer, DVM.) (From Quesenberry KE, Carpenter JW. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery*, 2nd ed. St Louis, 2004, Saunders.)

II. Ear mites
 A. Cause is *Psoroptes cuniculi*, a common parasite. Mites do not burrow but cause inflammation by biting and chewing the epithelial surface of the skin
 B. Clinical signs include thick, dry crusts on the inner surface of the ear pinna, with intense pruritus
 C. Diagnosis is by examination of the ear canal for mites or by microscopic examination of crusts and exudates
 D. Treatment
 1. Ivermectin is effective. Clean ears a few weeks after pain subsides. Apply antibiotic cream if there is secondary bacterial infection
 2. Mites are easily transmitted. Isolate affected rabbits, and keep cages clean
III. Fur and mange mites
 A. Causes: *Cheyletiella parasitivorax* is the common fur mite and is often called "walking" dandruff. Cheyletid mites are nonburrowing and may cause a transitory dermatitis in humans. Mange mites (*Sarcoptes, Notedres*) occur infrequently
 B. Clinical signs include a scaly dermatitis with flaky exudates. Mites are primarily on the dorsal trunk

and scapular region. Pruritus is not seen with *Cheyletiella* but is intense with mange mites
C. Diagnosis is by identification of *Cheyletiella* on cellophane tape preparations of affected skin. Mange mites require deep skin scrapings for identification (Figure 56-3)
D. Treatment
1. Ivermectin given subcutaneously (SC) is effective against most mites
2. Treat the environment with parasiticides, and isolate affected rabbits

IV. Myiasis
A. Cause: Fly larval infestation occurs in rabbits housed outdoors in warm weather
B. Clinical signs
1. Cuterebra larvae burrow into tissue causing SC swellings, usually in the ventral cervical, inguinal, hindquarter, dorsum, and axillary regions
2. Maggots burrow through large, moist necrotic areas at the base of the tail and dorsum. Secondary bacterial infections are common
C. Diagnosis is based on the presence of larvae in wounds
D. Treatment
1. Clip hair and remove larvae intact. May require sedation
2. Debride wounds, excise abscessed skin
3. Ivermectin can be used to kill larvae, but larvae will still need to be removed
4. Screen outdoor hutches

V. Superficial mycosis
A. Cause: Usually caused by *Trichophyton mentagrophytes* or occasionally by *Microsporum* spp. Transmission is by direct contact, fomites, or asymptomatic carriers. Humans are susceptible
B. Clinical signs are alopecia with erythema and scaly dermatitis on the head and ears. Lesions may extend to the neck, legs, feet, and nails
C. Diagnosis is based on culture findings. *T. mentagrophytes* does not fluoresce with ultraviolet light
D. Treatment is aimed at eliminating the organism and preventing spread
1. Clip hair and apply topical antifungal agents for 3 to 4 weeks. Lime sulfur dips can be used for 4 weeks. Wear gloves when treating or handling
2. Griseofulvin can be given orally for 4 weeks
3. Disinfect the environment

VI. Ulcerative pododermatitis
A. Causes: Sore hocks usually develop from management-related problems, such as wet conditions, abrasions from flooring, and restriction of movement (small cages or obesity). The plantar surface of the hocks is most commonly affected, and secondary bacterial infections may occur. Chronic lesions lead to abscesses or spread to bone
B. Clinical signs include thinning fur; raw, ulcerative sores; and scabs on the plantar surface. Rabbits may be lame or reluctant to move
C. Diagnosis is based on clinical signs and physical examination
D. Treatment
1. Correct environmental factors
2. Clean and debride wounds with astringents and antibiotic creams. Protect wounds with bandages. Healing may be prolonged
E. Prevention
1. Flooring should be smooth and nonabrasive
2. Cages should be kept clean and dry and sufficient in size to allow movement
3. Check feet and hocks periodically, and prevent obesity



Figure 56-3 *Cheyletiella parasitovorax* is often described as "walking dandruff." (From Mitchell MA, Tully TN. *Manual of Exotic Pet Practice*. St Louis, 2009, Saunders.).

RESPIRATORY DISEASE

I. Upper respiratory tract infection (snuffles)
A. Causes include *Pasteurella multocida, Bordetella bronchiseptica*, *Staphylococcus*, and *Pseudomonas* spp. Transmission is by direct contact, from doe to offspring, aerosolization, or fomites
B. Clinical signs include sneezing, rhinitis, mucopurulent nasal discharge, conjunctivitis, and ocular discharge
C. Diagnosis is based on clinical signs and isolation of causative agent via culture and sensitivity testing. Radiographs may be useful
D. Treatment: Antibiotics should be given when respiratory disease is first noted. Topical ophthalmic antibiotics may be used if conjunctivitis is present. Long-term therapy may be necessary

II. Pneumonia
A. Pasteurellosis is the most common cause, but *Bordatella bronchiseptica* or *Staphylococcus aureus* may be involved
B. Stress plays a role, and temperature changes, poor sanitation, or poor ventilation contribute to development
C. Clinical signs include labored breathing, weight loss, cachexia, anorexia, or acute death
D. Diagnosis is made by auscultation or thoracic radiographs. A complete blood cell count (CBC) may indicate an increase in heterophils, indicating an inflammatory response

E. Treatment with parenteral antibiotics is preferred in rabbits with severe pneumonia. Supportive therapy includes supplemental fluids, vitamins, and force-feeding. Severely dyspneic rabbits may be placed in an oxygen cage

III. Pasteurellosis
A. Cause is *Pasteurella multocida*, an endemic disease of rabbits. Infection is spread by direct contact with infected rabbits or fomites, aerosolization, or from doe to offspring
B. Clinical signs depend on the site and chronicity of infection. Respiratory signs, neurologic signs, abscesses, general illness, or death may result
C. Diagnosis is by isolating *P. multocida* from exudates, blood, or tissue. Enzyme-linked immunosorbent assays may detect antibodies to *P. multocida* and can help detect subclinical carriers
D. Treatment
1. Successful treatment can be difficult
2. Antibiotic therapy depends on culture and sensitivity. Enrofloxacin or chloramphenicol given for several months has been used successfully. Injectable penicillin may also be effective
3. Abscesses require debridement and wound care
4. Supportive therapy may be necessary
E. Prevention is difficult because pasteurellosis is endemic. Isolate diseased animals, and eliminate them from breeding colonies. Examine rabbits closely before purchase, and quarantine new rabbits away from other rabbits. Maintain good sanitation, minimize stress, and feed a proper diet

GASTROINTESTINAL DISEASES

I. Diarrhea, enteritis, enterotoxemia
A. Causes
1. Bacteria, such as *Clostridium spiroforme*, are primary pathogens in bacterial enteritis. *Escherichia coli* causes diarrhea in young rabbits, and *Clostridium piliforme* (Tyzzer disease) causes acute diarrhea and death, primarily in young weanling rabbits. *Lawsonia intracellularis* can cause enterocecocolitis in weanling rabbits
2. Viruses such as coronavirus can cause diarrhea and death in 3- to 10-week old rabbits. Rotavirus my also be a pathogen
3. Parasites such as coccidiosis primarily affect young rabbits. *Cryptosporidia parvum* may also cause transient diarrhea in young rabbits for 3 to 5 days
4. Antibiotic therapy suppresses the normal gut flora and may cause diarrhea. Stress is also a major factor in diarrhea. Lack of roughage can also cause diarrhea
B. Clinical signs include soft, pasty stool to profuse liquid. The hindlimbs and perineal region may be stained with feces. Severe diarrhea may lead to lethargy, anorexia, weight loss, and dehydration. Sudden death may be the only clinical sign if peracute
C. Diagnosis is based on clinical signs and history. Fecal flotation, culture, and sensitivity may be helpful
D. Treatment
1. Increase the roughage in the diet if this is deficient
2. Lactobacillus supplements may help restore normal gut flora
3. Metronidazole can be used to treat *C. spiroforme*; enrofloxacin or trimethoprim-sulfa is used for *E. coli*; and chloramphenicol is used to treat *L. intracellularis*
4. Fluid therapy may be needed to combat dehydration. Anorectic animals should be force-fed
E. Prevention includes feeding adequate roughage, minimizing stress in young or weanling rabbits, and isolating affected animals from healthy rabbits. Sanitation is important

II. Coccidiosis
A. Cause is usually *Eimeria perforans*. Infection is from ingestion of oocysts. It is primarily a disease of young and weanling rabbits
B. Clinical signs include intermittent mild to moderate diarrhea and dehydration. Severe diarrhea or death may occur with heavy infections. Hepatic coccidiosis is associated with anorexia, weight loss, diarrhea, or acute death
C. Diagnosis is based on identifying *Eimeria* oocysts in a fecal sample
D. Treatment
1. Trimethoprim-sulfamethoxazole is effective for prevention and treatment of coccidiosis
2. Sanitation is important for therapy and prevention. Screen rabbits for shedding of oocysts. Cull carriers from colonies. Check all young rabbits for coccidia

III. GI stasis
A. Cause: Lack of roughage in the diet, stress, and hairballs are predisposing factors
B. Clinical signs include lack of fecal pellet formation for longer than 24 hours, anorexia, painful abdomen, hunched position, distended stomach or cecum
C. Diagnosis: Dietary history is important in the diagnosis, with lack of fiber or roughage
D. Treatment
1. Fluids should be administered SC or parenterally if critical
2. If the diet is deficient or marginal in fiber, this should be corrected
3. Broad-spectrum antibiotics, such as fluorinated quinolones, trimethoprim-sulfa, or chloramphenicol may be given if bacterial enteritis is present. Antibiotics may be given orally or parenterally if clinical signs are severe. Anorectic rabbits should be force-fed with softened rabbit pellets mixed with vegetable baby food
E. Prevention: Stasis may be prevented by feeding a diet with an adequate content of fiber. Stress should also be minimized in young and weanling rabbits

IV. Malocclusion
 A. Cause: Malocclusion is the most common cause of anorexia in rabbits
 B. Clinical signs include anorexia and excessive salivation
 C. Diagnosis is by examination of the mouth
 D. Treatment
 1. Incisors can be cut with a diagonal cutter or dental drill. Do not use guillotine-type nail clippers. Incisors should be clipped every 4 to 8 weeks
 2. Molar malocclusion treatment requires sedation with an injectable tranquilizer. With the rabbit in sternal recumbency, a dental drill can be used to smooth sharp edges. Treatment may be needed as often as every month
 3. Those with malocclusion should not be bred. Feed a high-roughage diet to encourage normal wear of the teeth

V. Hairballs (Trichobezoars)
 A. Etiology. Diets may be inadequate in roughage. Long-haired breeds may consume excessive hair during grooming. Mineral deficiencies, hormonal influences during breeding, or boredom may cause fur-barbering. Rabbits cannot vomit, so hair accumulates in the stomach
 B. Clinical signs include anorexia, weight loss, depression, intestinal gas, small fecal pellets, hair in feces, diarrhea
 C. Diagnosis
 1. Suspect a hairball if the rabbit is anorectic but alert, there is a history of inadequate dietary roughage, and malocclusion is not present
 2. A soft mass in the stomach is usually palpable. Radiographs or ultrasonography may be helpful
 D. Treatment
 1. Medical treatment is usually effective. Encourage movement; GI motility stimulants and petrolatum-based oral lubricants can be given. Give free-choice hay and fresh vegetables ad libitum
 2. Rarely, surgery may be indicated
 E. Prevention: Encourage exercise, brush long-haired rabbits regularly, and feed adequate dietary fiber

UROGENITAL AND REPRODUCTIVE DISEASES

I. Uterine adenocarcinoma and hyperplasia
 A. Causes
 1. Uterine adenocarcinoma is the most common tumor in rabbits. Usually occurs in does that are older than 4 years; incidence ranges from 50% to 80%
 2. Local metastasis can invade lymph nodes; hematogenous spread occurs late in the clinical course
 B. Clinical signs
 1. This is a slow-growing tumor, so there are usually few clinical signs in the early stages
 2. Decreased litter size, stillbirths, dystocia, infertility are seen in breeding does. Many have associated cystic mastitis. Depression, lethargy, anorexia, dyspnea, and ascites may occur in later stages
 C. Diagnosis: A thickened uterus or multiple abdominal masses may be palpable. Radiographs or ultrasonography can be useful. Thoracic radiographs should be taken to identify metastases
 D. Treatment involves ovariohysterectomy before metastasis. Prognosis is poor if pulmonary metastasis has occurred, and euthanasia is recommended in such cases
 E. Prevention: Ovariohysterectomy of does before 2 years of age or in those older than 3 years of age with evidence of cystic mastitis or aggressive behavior

II. Mastitis
 A. Causes
 1. Septic mastitis is common in lactating does from abrasions, heavy lactation, or poor sanitation. *Staphylococcus aureus*, *Pasteurella*, and *Streptococcus* are most common
 2. Nonseptic, cystic mastitis is seen in females older than 4 years of age. It may be associated with high estrogen levels, uterine hyperplasia, or uterine adenocarcinoma
 B. Clinical signs of septic mastitis include swollen, firm, blue-tinged, warm mammary glands. Abscesses can develop, and systemic signs may be present. With nonseptic mastitis, glands are swollen, firm, blue-tinged with serosanguinous discharge but no systemic signs
 C. Diagnosis is based on clinical signs, history, culture and sensitivity, fine-needle aspiration and cytology
 D. Treatment
 1. For septic mastitis, give antibiotics and pain medication if needed. Warm compresses may help. Suckling kits should not be allowed to nurse
 2. Cystic mastitis resolves following ovariohysterectomy

III. Dysuria, hematuria
 A. Causes: Hematuria is common in cystitis, or can indicate uterine adenocarcinoma. Cystic calculi can occur in both males and females and are usually calcium carbonate or calcium oxalate
 B. Clinical signs are usually absent if discoloration is due to pigments or excessive calcium in the urine. Dysuria, stranguria, urine scald, lethargy, anorexia, and depression may be seen with cystitis or calculi
 C. Diagnosis
 1. Urine dipstick can be used to determine hematuria. Urinalysis, serum chemistry, and CBC can assess renal function
 2. Obtain abdominal radiographs if calculi are suspected
 3. Uterine adenocarcinoma is likely in does older than 3 years of age with a thickened uterus and multiple abdominal masses

D. Treatment
1. Treatment is not needed if discoloration is due to pigments. Decrease calcium in the diet in rabbits with hypercalciuria by feeding grass hay rather than alfalfa hay
2. Antibiotics are used for about 3 weeks in cases of cystitis. Calculi can be removed surgically

IV. Treponematosis
A. Cause: *Treponema paraluiscuniculi* causes rabbit syphilis and is transmitted by direct and venereal contact. It is not zoonotic
B. Clinical signs are erythematous vesicles that progress to papules, ulcerations, scaliness, and dry crusty lesions on external genitalia, perineum, nose, eyelids, lips, and chin. Abortions, metritis, and infertility may be increased in breeding does
C. Diagnosis is based on history, clinical signs, distribution of lesions, and response to therapy. Organisms can be identified by dark-field microscopy of skin scrapings. Serologic tests are available
D. Treatment is injectable penicillin once weekly for 2 to 3 weeks. Response is rapid

NEUROMUSCULAR AND SKELETAL DISEASES

I. Mandibular and joint abscesses
A. Causes
1. Occur frequently. Common bacteria include *Pasteurella*, *Staphylococcus*, and *Pseudomonas*. Many other bacteria have been isolated
2. Malocclusion and elongated teeth often accompany mandibular abscesses. Soft tissue abscesses can occur in the oral cavity or joints secondary to a penetrating wound

B. Clinical signs
1. Joint abscesses are often in the distal limbs. Rabbits may be lame
2. Mandibular abscesses may become large before they are noticed. Excessive salivation may be an early sign, and rabbits may refuse to eat. However, many rabbits have no clinical signs

C. Diagnosis is based on aspirate of the swelling. Radiographs may be helpful, and tissue samples should be submitted for culture and sensitivity
D. Treatment
1. Lancing is ineffective. Complete surgical excision of the abscess is preferred. Abscesses often recur
2. Amputation of an affected limb may be the best option. Abscesses may recur in other joints because of hematogenous spread
3. Long-term antibiotic therapy and nursing care are necessary
4. Prognosis is guarded

II. Torticollis-head tilt-ataxia
A. Cause: Bacterial infection (usually *Pasteurella multocida*) of the middle or inner ear or meninges is the most common cause. *Encephalitozoan cunuculi* may also cause torticollis
B. Clinical signs can be acute or progressive. Some rabbits have no other clinical signs
C. Diagnosis is based on clinical signs
1. Thoroughly examine the ears. The base of the ears may be swollen, and debris can often be massaged out of the ear canal
2. Radiographs of the skull or serology may be useful
3. A diagnosis is sometimes based on response to therapy

D. Treatment
1. Antibiotics (chloramphenicol or enrofloxacin) are given for a minimum of 4 to 6 weeks
2. Clean ears thoroughly and administer topical antibiotics three to four times daily
3. Give oral lactobacillus during long-term antibiotic therapy
4. Supportive care may be necessary
5. Euthanasia is chosen in debilitated rabbits or in those that do not respond to therapy

III. Encephalitozoonosis (*Encephalitozoan cunuculi*)
A. Causes
1. Infects rabbits, mice, rats, hamsters, and guinea pigs
2. Major route of transmission is by ingestion of contaminated urine. Spores can survive for 4 weeks in a mild environment
3. Infects lungs, kidneys, liver, heart, brain, and eyes. Many infections are asymptomatic

B. Clinical signs depend on the site of infection and may include torticollis, ataxia, seizures, and death
C. Diagnosis is based on clinical signs. Serologic tests are available to detect antibodies against *Encelphalitozoan* spp. Definitive diagnosis requires histopathology of affected tissues
D. Treatment is with fenbendazole, oxibendazole, or albendazole for 30 to 90 days. Clinical signs may recur when medication is discontinued. Supportive care may be necessary
E. Prevention: Carriers can be identified with serologic testing and should be eliminated. Eliminate urine contamination between cages, and maintain good sanitation. Prevent contact of domestic rabbits with wild rabbits

IV. Vertebral fractures-luxation
A. Causes: A strong kick of the hindlegs can result in fracture of the spine, especially if poorly restrained. The most common site of fracture or luxation is in the lumbosacral region (L7)
B. Clinical signs are acute and may include vocalization, partial or complete paralysis of the rear legs, and loss of bladder and bowel function
C. Diagnosis is based on history, clinical signs, and radiographs
D. Treatment
1. Steroids can be administered if the diagnosis is made within 6 to 12 hours after the fracture
2. Cage rest and antiinflammatory agents can be used in mild cases. Surgery is usually not successful
3. Prognosis for recovery is poor. Euthanasia is recommended in cases with rear limb paralysis and urinary and fecal incontinence

V. Bone fractures, joint luxations
 A. Causes: Their light skeleton allows the tibia, radius, and ulna to fracture easily with trauma
 B. Clinical signs include acute lameness, open fractures, or palpable fractures
 C. Diagnosis is based on history, clinical signs, physical examination, and radiographs
 D. Treatment
 1. Splints or intramedullary pins can be used for most fractures. External skeletal fixation may be necessary in some cases
 2. Amputation may be best if the fracture is comminuted or open
 3. Postoperative care includes radiographic evaluation, cage rest, good diet, cleanliness, and frequent monitoring of bandages. Antibiotics may be indicated if the fracture is open

Supplemental Reading

Chen S, Quesenberry KE. Rabbits. In Birchard SJ, Sherding RG, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1858-1880.

Quesenberry KE, Carpenter JW, editors. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery.* 2nd ed. St Louis, 2004, Saunders.

57 CHAPTER

Rodents

Patricia A. Schenck

HUSBANDRY

I. Caging and sanitation
 A. Cages need to be made of material that is easily cleaned and resistant to chewing
 B. If mesh floors are used, pay attention to the size of the mesh to prevent foot problems
 C. Clean cages frequently and maintain good sanitation
 D. Provide objects for gnawing and exercise
 E. Maintain the room temperature between 70° and 75° F
II. Nutrition
 A. Feed a commercial pelleted diet designed for that species
 B. Supplement all guinea pigs with vitamin C
 C. Sipper bottles are best for providing water. Change the water daily so that it is always fresh

ROUTINE PROCEDURES

I. Blood samples
 A. The lateral or medial saphenous veins can be used in larger animals (over 100 g)
 B. The cephalic vein can be used in guinea pigs
 C. Use tail bleeding only if blood cannot be obtained from another site
II. Injections
 A. Give subcutaneous (SC) injections over the shoulder blades
 B. Give intramuscular injections in the caudal thigh muscles
III. Euthanasia is performed by induction of inhalant anesthesia followed by an overdose of barbiturates
IV. Hemostasis is very important because of the small blood volume of these animals

DISEASES OF MICE

I. Dermatology
 A. Ectoparasites
 1. Fleas, lice, and mites affect mice, causing alopecia on the head and dorsal midline
 2. Treat fleas or lice with pyrethrin powder. Treat mites with ivermectin
 3. Thoroughly clean the cage; the environment may also need to be treated
 B. Dermatophytosis also can occur. Treat with griseofulvin
 C. Bacterial disease
 1. *Staphylococcus aureus* causes ulcerative dermatitis resulting in pododermatitis, mastitis, and abscesses. Treat with appropriate antibiotics
 2. *Escherichia coli, Pasteurella, Klebsiella, Pseudomonas*, or *Streptococcus* can also cause mastitis. Treat with antibiotics and improve sanitation
 3. *Actinobacillus* or *Corynebacterium* can cause SC abscesses. Treat with ampicillin
 4. Males commonly have preputial gland abscesses caused by *E. coli* or *S. aureus*. Treat topically
 D. Neoplasic
 1. Mammary neoplasia is common and is usually malignant. Metastasis to the lungs is common
 2. Lymphoma also commonly causes SC masses
 E. Otitis
 1. Otitis externa is usually caused by ear mites. Treat by cleaning debris and administering ivermectin
 2. Otitis media or interna is caused by invasion of bacteria from an abscess. Head tilt is common
 F. Miscellaneous
II. Ophthalmology
 A. Epiphora is commonly caused by poor sanitation or overgrown incisors. It may also be an early sign of respiratory disease
 B. Retinal degeneration, cataracts, and other ophthalmic conditions also occur
III. Respiratory
 A. Murine respiratory mycoplasmosis is a common respiratory disease caused by *Mycoplasma pulmonis*. The disease is activated by stress and can remain dormant for long periods. Signs include dyspnea, mucopurulent discharge, and anorexia. Treat with tylosin and nutritional support. Survivors are carriers and should be quarantined
 B. Sendai virus is a common cause of pneumonia that causes acute death in suckling or weanling mice. Treat with antibiotics. A vaccine is available; animals that recover are resistant to future infection
 C. Bacterial pneumonia is typically caused by *Streptococcus, Corynebacterium, Pasteurella, Pseudomonas*, and *Klebsiella*. Treat with appropriate antibiotics

D. Mammary adenocarcinomas may metastasize to the lungs, causing respiratory signs

IV. Gastroenterology
 A. Parasites
 1. *Hymenolepis nana* is a tapeworm that usually does not cause clinical signs. However, it is directly transmissible to humans. Treat with praziquantel and improve sanitation
 2. Pinworms cause anal pruritus and rectal prolapse. Treat with piperazine or fenbendazole
 3. *Spironucleus muris* is a protozoa that causes diarrhea in young mice. Treat with oxytetracycline and improve sanitation
 4. *Giardia* spp. can cause diarrhea and is zoonotic. Treat with metronidazole
 5. *Cysticercus fasciolarus* causes hepatic cysts, which are the infective form of *Taenia taeniaformis* in carnivores
 B. Diarrhea
 1. Viral diseases
 a. Lethal intestinal virus of infant mice causes diarrhea in mice 10 to 20 days old. Treat supportively; those that survive should be quarantined
 b. Epizootic diarrhea of infant mice usually occurs in mice less than 2 weeks old, with low mortality. Treat supportively and quarantine survivors
 c. Mouse hepatitis virus causes yellow diarrhea and encephalitis in 1- to 2- week-old mice. Older animals show progressive hepatitis. Treat supportively and quarantine survivors
 d. Reovirus causes an oily diarrhea in older suckling mice. Most affected mice eventually die
 2. Bacterial diseases
 a. Transmissible murine colonic hyperplasia caused by *Citrobacter freundii* results in diarrhea, rectal prolapse, and stunted growth. Treat with appropriate antibiotics
 b. Salmonellosis (mouse typhoid) is usually caused by contaminated feed and results in anorexia, conjunctivitis, arthritis, and diarrhea. Treat supportively and quarantine survivors. Sanitation is important because *Salmonella* is zoonotic
 c. *Bacillus piliformis* causes Tyzzer disease with high mortality in weanlings. Treat with tetracycline and reduce stress
 C. Overgrown incisors are common

V. Theriogenology
 A. Infertility can be due to poor management, poor nutrition, or crowding
 B. Pyometra is also common

VI. Urology
 A. Glomerulonephritis is common in old mice and may be secondary to viral infection
 B. In aged male mice, urethral obstruction may develop from plugs of inspissated ejaculum. Hematuria may be present before obstruction. Surgical removal is required
 C. Mice can be carriers of leptospirosis

VII. *Streptobacillus moniliformis* causes infectious polyarthritis. Treat with antibiotics and supportive care

VIII. Neurology
 A. Head tilt is common, resulting from otitis media. Trauma is also a common cause of neurologic signs
 B. Lymphocytic choriomeningitis is caused by an arenavirus. Acute signs include photophobia and seizures and typically occur in 3- to 6-week old mice. Glomerulonephritis develops later. If infected after weaning, there is weight loss, arthritis, and conjunctivitis
 C. Theiler disease is a poliomyelitis-encephalomyelitis that causes encephalitis in very young mice. Mice 6 to 10 weeks of age show rear limb weakness progressing to paralysis. Albino mice are predisposed. Treat supportively
 D. Seizures may occur from trauma, otitis, renal failure, liver failure, sepsis, meningitis, encephalitis, or neoplasia

IX. Hematology
 A. *Eperythrozoon coccoides* is a rickettsial parasite found in red blood cells (RBCs). Transmission is via the louse, but affected mice generally have no symptoms. Treat with tetracyclines
 B. Leukemia is transmitted through mammary tissue or through the placenta and is viral in origin

DISEASES OF RATS

I. Dermatology
 A. Mammary tumors are common, developing in 59% to 90% of adult females and 15% of adult males. Most are benign fibroadenomas
 B. Fleas, lice, and mites infest rats as in mice
 C. Ulcerative dermatitis caused by *Staphylococcus aureus* also occurs in rats as in mice
 D. Fibrous bands of tissue can form around the tail if the environmental humidity is less than 40% and can result in gangrene of the tail. Incise the ring of tissue and apply DMSO, steroid, and antibiotics. Keep humidity above 50% to prevent ringtail

II. Ophthalmology
 A. Sialodacryoadenitis virus is a coronavirus that causes keratoconjunctivitis, uveitis, periorbital swelling, and pneumonia. There is typically no loss of activity or appetite. Treatment is usually not necessary in mild cases. If respiratory signs occur, treat with antibiotics
 B. *Mycoplasma, Streptococcus, Pseudomonas* spp., and others may cause mucopurulent ocular discharge
 C. Cataracts may develop secondary to diabetes mellitus, or they may be primary

III. Respiratory
 A. Murine respiratory mycoplasmosis is common in rats
 B. *Streptococcus pneumoniae* may cause bacteremia with stress
 C. *Cornebacterium kutscheri, Pasteurella pneumotropica,* and *Pseudomonas aeruginosa* can cause respiratory signs

D. *Pneumocystosis carinii* is a protozoa infecting lungs. Signs only occur in older or immunocompromised rats. Treat with sulfas

IV. Cardiovascular system
A. Congestive heart failure is common in older rats. Treat supportively and give furosemide and digitalis
B. Polyarteritis nodosa in older rats causes thickening of the arteries, which predisposes them to clot formation and aneurysms

V. Gastroenterology
A. Rats do not have a gallbladder
B. Parasites include nematodes, cestodes, and protozoa, similar to those in mice
C. *Capillaria hepatica* causes no clinical signs, but yellow streaks on the liver are observed at necropsy
D. Malocclusion occurs as in mice
E. Rats 1 to 2 weeks of age are susceptible to epizootic diarrhea of suckling rats. Most recover. *Salmonella* may also cause diarrhea

VI. Theriogenology
A. Females develop a post-copulatory plug after breeding
B. Infertility may be due to poor nutrition, age, or improper husbandry practices

VII. Urology
A. Urinary stones are common in older rats and are usually ammonium magnesium phosphate or calcium carbonate
B. Nephrocalcinosis and progressive nephropathy are very common in older rats. Treat chronic renal failure (CRF) supportively
C. *Trichasomoides crassicauda* is a parasite of the rat kidney and may cause hematuria and stranguria. Treat with methyridine

VIII. Neurology
A. *Streptobacillus moniliformis* is present in many middle-ear infections and chronic pneumonias. Head tilt is commonly seen
B. Head tilt may also be due to trauma or neoplasia
C. Radiculoneuropathy is common in older rats, with posterior paresis progressing to paralysis. Treat supportively

IX. *Hemobartonella muris* is a parasite within RBCs and is nonpathogenic unless the immune system is compromised. Signs may include hemolytic anemia. Treat with tetracyclines

DISEASES OF HAMSTERS

Hamsters are very sensitive to many antibiotics, including penicillins, clindamycin, lincomycin, streptomycin, tylosin, erythromycin, and cephalosporins. Antibiotic therapy often allows overgrowth of pathogenic bacteria, especially *Clostridium difficile*. Diarrhea ensues and is usually fatal. Discontinue antibiotics, give a *Lactobacillus* supplement, and treat supportively.

I. Dermatology
A. Mites include *Demodex, Sarcoptes,* and *Notoedres*. *Demodex* spp. are usually seen in immunocompromised animals; treat with amitraz. *Sarcoptes* may cause facial alopecia; treat with ivermectin. *Notoedres* in the female is usually in the external ear canal but may be on the ears, feet, tail, and genitalia in males. Treat with ivermectin
B. SC masses are usually abscesses caused by *Pasteurella pneumotropica, Staphylococcus*, or *Streptococcus*. Treat with appropriate antibiotics

II. Ophthalmology
A. Eye rupture occurs following trauma or infection. Surgical enucleation is the treatment of choice
B. Conjunctivitis is common. Mucopurulent discharge is usually caused by *Pasteruella* or *Streptococcus* spp.

III. Respiratory
A. Viral respiratory infections of humans can infect hamsters. Treat supportively. Use antibiotics only if there is considerable nasal discharge, dyspnea, or anorexia
B. Dyspnea is usually due to thoracic trauma. Epistaxis is usually seen with trauma. Treat supportively
C. Pneumonia is usually caused by *Yersinia pseudotuberculosis*, *Pasteurella pneumotropica*, or *Streptococcus* spp. These agents tend to form abscesses. Treat with chloramphenicol. Recovered hamsters are carriers and should be quarantined

IV. Thrombosis in the left atrium is seen in many geriatric hamsters. Usually secondary to cardiomyopathy, amyloidosis, or sepsis. Signs include dyspnea and acute death

V. Gastroenterology
A. Parasites
1. Tapeworm *Hymenolepis nana*. Treat with praziquantel
2. Pinworms. Treat with fenbendazole
B. Dental-oral
1. Dental caries can cause abscesses. Extract tooth and administer antibiotics
2. Overgrown incisors occur
3. Cheek pouch impaction can occur. Remove material with forceps. If fungal or bacterial infection is suspected, culture and administer antibiotics
C. Diarrhea
1. *Campylobacter*-like organisms cause proliferative ileitis or "wet-tail disease"
a. Young hamsters (between 3 and 8 weeks of age) are usually affected, and most die
b. There is abdominal pain, and rectal prolapse is common
c. Treat with neomycin, tetracycline, or metronidazole; prognosis is poor
2. Bacteria causing diarrhea include *E. coli, Salmonella*, or Tyzzer disease
D. Polycystic disease is characterized by multiple cysts in liver, pancreas, epididymis, and seminal vesicles in animals greater than 1 year of age. Finding is incidental and no treatment is recommended

VI. Theriogenology
A. Females can be very aggressive toward males, so monitor carefully during breeding
B. After a successful mating, a malodorous vaginal discharge appears about 2 days later
C. Normal gestation length is 15 to 16 days

VII. Urology
 A. Renal amyloidosis develops in most geriatric hamsters
 B. Signs include those of CRF, edema and ascites. Treat supportively
VIII. Neurology
 A. Head tilt is secondary to otitis media but could be due to neoplasia or lymphocytic choriomeningitis
 B. Cage paralysis is seen in hamsters fed all-seed diets that get little exercise. Rule out trauma, and provide vitamin D and E supplementation, better nutrition, and exercise. This is usually curative in mild cases
IX. Lymphoma and lymphosarcoma occur and may be viral in origin

DISEASES OF GERBILS

I. Dermatology
 A. *Demodex* is rare. Treat with amitraz
 B. Acute moist dermatitis is caused by *S. aureus* and often begins on the face under matted secretion from the harderian glands. Treat with appropriate antibiotics (Figure 57-1)
 C. Alopecia is usually from trauma, especially on the face
 D. The most common tumors are sebaceous gland adenomas, basal cell tumors, or squamous cell carcinoma. Melanomas are most frequent on the ears, feet, or base of tail
II. Ophthalmology: Epiphora is common in high-ammonia environments. Treat by improving the environment
III. Gastroenterology
 A. Tapeworms and pinworms can occur
 B. Incisor overgrowth can occur, causing anorexia
 C. Diarrhea
 1. *Salmonella* is usually a contaminant in feed and causes transient diarrhea. Most animals recover
 2. Tyzzer disease (*Bacillus piliformis*) causes diarrhea in weanlings and in postpartum females. At necropsy, yellow-gray nodules are found in the liver. Treat with oxytetracycline
 D. Animals fed excessive fat may develop gallstones or hepatic lipidosis
IV. Theriogenology
 A. For breeding, gerbils should be paired early in life
 B. Chronic vulvar discharge usually suggests ovarian tumors or cystic ovaries. Ovariohysterectomy is the treatment of choice
V. Chronic renal failure is common in older gerbils. Treat supportively
VI. Epileptic seizures may be common in some family lines and are stress-induced. No treatment is necessary

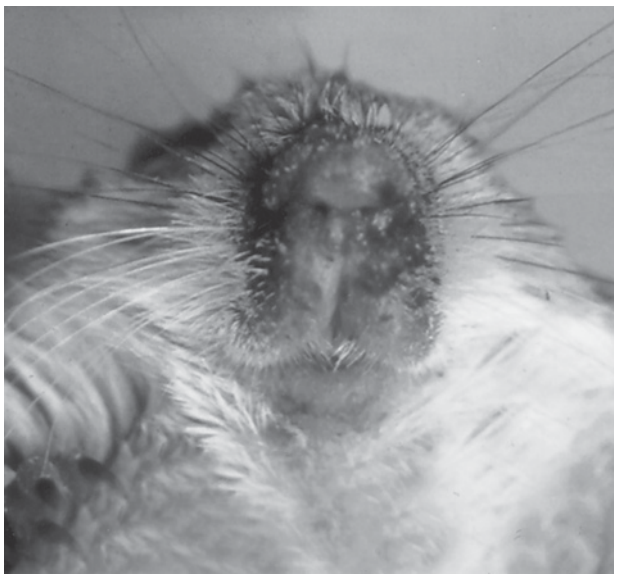


Figure 57-1 Sore nose (facial eczema, nasal dermatitis) in a gerbil. This condition may result from an increase in harderian gland secretion complicated by infection with *Staphylococcus* spp. (From Quesenberry KE, Carpenter JW, editors. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery.* 2nd ed. St Louis, 2004, Saunders.)

DISEASES OF CHINCHILLAS

Avoid the use of penicillin, erythromycin, lincomycin, and cephalosporins in chinchillas. Chinchillas are sensitive to heat and overheat quickly.

I. Dermatology
 A. Fur chewing
 1. May be related to stress, poor environment, chronic disease, or poor nutrition
 2. Do skin scrapings, fecal examination, complete blood cell count, fungal culture, and skin biopsy to help diagnose any underlying problem. Treat accordingly
 B. Dermatophytes also occur
 C. Chinchillas require dust baths weekly for good skin condition. Use only commercially available chinchilla dust
II. Ophthalmology: The most common problems are conjunctivitis, cataracts, and asteroid hyalosis
III. Pneumonia
 A. Usually caused by *Staphylococcus* or *Bordetella*
 B. Treat with chloramphenicol, sulfas, or enrofloxacin
IV. Gastroenterology
 A. Diarrhea
 1. Usually caused by *Coccidia, Giardia*, or bacteria. *Clostridium, Pseudomonas, E. coli, Salmonella*, and *Pasteurella* are most common and often are from contaminated feed. *Pasteurella pseudotuberculosis* causes chronic weight loss or acute death, and enlarged mesenteric lymph nodes are typically found
 2. Diagnose by fecal smear or bacterial culture
 3. Treat with appropriate antibiotics. Prognosis is poor for *Pasteurella pseudotuberculosis*
 B. Tapeworms can occur
 C. Malocclusion of the teeth can also occur
V. Theriogenology
 A. Dystocia is common
 B. Metritis
 1. Caused by bacteria from the male or by an internal abscess

2. Signs include vaginal discharge, anorexia, weight loss, evidence of abdominal pain, polyuria, polydipsia
3. Ovariohysterectomy is the treatment of choice

C. Mastitis
1. Mammary glands are swollen and feel hot. Neonates become restless and lethargic
2. Culture milk, and treat with appropriate antibiotic. Hot packs may also be helpful. Use milk replacer to feed neonates, or foster them to another female

D. Penile hair rings
1. Check at least four times yearly for hair encircling the penis
2. Lubricate, remove hair, and treat any ulcerations

VI. Neurology
A. *Listeria monocytogenes*
1. Chinchillas are sensitive to *Listeria*. Signs include central nervous system (CNS) signs, lethargy, anorexia, abortion, hepatitis, enteritis, pneumonia
2. Treat with sulfa drugs

B. Other causes of CNS signs in chinchillas include thiamine deficiency, lead poisoning, *Streptococcus*, roundworm, or choriomeningitis

DISEASES OF GUINEA PIGS

Guinea pigs require dietary vitamin C and are sensitive to many antibiotics, including penicillins, tetracyclines, lincomycin, erythromycin, cephalosporins, and others.

I. Dermatology
A. Fleas, lice, and mites occur
1. Treat lice with ivermectin or pyrethrin shampoo. Lice occasionally cause alopecia
2. The *Trixacarus caviae* mite causes severe pruritus and affects mostly postpartum females. Alopecia is common down the dorsal midline. Treat with ivermectin
3. The mite *Chirodiscoides caviae* occurs in the perineal regions. Treat with carbaryl or lime-sulfur dip

B. Trichophyton mentagrophytes
1. Alopecia and dry skin are common, starting on the face and spreading down the back. Treat with griseofulvin, topical iodine, and chlorhexadine shampoos
2. Barbering can also cause alopecia

C. Cervical lymphadenitis is caused by *Streptococcus zooepidemicus* and *Streptobacillus moniliformis*. Enlarged lymph nodes in the ventral neck region are present. Treat with chloramphenicol or sulfas; treat abscesses. Animals remain carriers

D. Mammary tumors can be benign or be adenocarcinomas

E. Pododermatitis is common. Signs include sores and ulcers on the feet to abscesses and gangrene. Overgrown toenails, poor sanitation, and wire flooring contribute to pododermatitis. Improve sanitation and environment, use sulfa drugs and treat abscesses (Figure 57-2)



Figure 57-2 Severe, ulcerative pododermatitis in a guinea pig. (From Mitchal MA, Tully TM. Manual of Exotic Pet Practice. St Louis, 2009, Saunders.)

II. Ophthalmology
A. *Chlamydia psittaci* causes inclusion body conjunctivitis
B. An early sign of vitamin C deficiency is dry ocular discharge
C. Cataracts can occur. Diabetes mellitus may be the cause in some cases

III. Respiratory
A. Nasal discharge may be associated with upper respiratory tract infection or allergies or irritants
B. About 30% of guinea pigs over 3 years of age develop bronchogenic papillary adenoma
C. Pneumonia
1. Caused by *Staphylococcus* or *Bordetella* commonly. *Pasteurella* or *Klebsiella* can also cause pneumonia. *Bordetella* may also cause abortions, and dogs, cats, rabbits, and rats are reservoirs for *Bordetella*
2. Deficiency of vitamin C may predispose guinea pigs to pneumonia
3. Treat with chloramphenicol, sulfas, or enrofloxacin

IV. Cardiology
A. Rhabdomyomatosis is commonly found at necropsy, and significance is unknown
B. Pale foci are noted in the endomyocardium and valves and histologically reveal excessive glycogen

V. Gastroenterology
A. Parasites
1. *Eimeria caviae*
a. *Coccidia* that is a common cause of diarrhea
b. Clinical signs of diarrhea, tenesmus, dehydration, death
c. Diagnose by fecal examination
d. Treat with sulfa drugs
2. *Paraspidodera ucinata*
a. Cecal pinworm
b. Usually asymptomatic, but can cause diarrhea and weight loss
c. Diagnose by fecal examination
d. Treat with fenbendazole or piperazine



Figure 57-3 Malocclusion of incisors in a guinea pig. (From Quesenberry KE, Carpenter JW, editors. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery.* 2nd ed. St Louis, 2004, Saunders.)

3. Other parasites
 a. *Cryptosporidium wrairi* and *Giardia* are rarely found and cause chronic enteritis
 b. *Balantidium* are nonpathogenic

B. Dental
1. Malocclusion causes ptyalism and anorexia (Figure 57-3)
2. Hypovitaminosis D may predispose to malocclusion

C. Diarrhea
1. Vitamin C deficiency causes soft, malodorous stool. Treat with vitamin C supplement
2. *Salmonella, E. coli, Arizona, Clostridium*, and *Yersinia pseudotuberculosis* can cause diarrhea
 a. *Salmonella* frequently causes light-colored diarrhea and is usually caused by contaminated feed. Use sulfas, but animals remain carriers
 b. Spores of *Clostridium* are usually seen on a Gram stain of feces. Treat with metronidazole
 c. *Y. pseudotuberculosis* can cause acutely fatal diarrhea, or it can localize in lymph nodes. Treat by removal of affected lymph nodes and with sulfa drugs

VI. Theriogenology
A. Dystocia is common in females bred after they are 6 to 9 months of age as a result of fusing of the pubic symphysis. A cesarean section is necessary
B. Pregnancy toxemia occurs in obese sows with large litters in late pregnancy. Signs include tachypnea, depression, seizures, and icterus. Treat with fluids, steroids, and calcium
C. Hemorrhagic syndrome occurs when a large litter compresses the portal vein and liver, resulting in vitamin K and clotting deficiency. Treat with vitamin K supplement
D. Vaginal discharge may be caused by a foreign body, pyometra, urinary tract infection, or neoplasia. Treat the underlying condition
E. Cystic ovaries can cause alopecia and abdominal enlargement. Ovariohysterectomy is the treatment of choice
F. Preputial foreign bodies are common in males. Sebaceous secretions around the perineal area in males should also be cleaned periodically to prevent pyoderma

VII. Cystitis and urinary stones are common. Treat with antibiotics and remove stones

VIII. Musculoskeletal
A. Overgrown toenails are common in guinea pigs and can cause pododermatitis
B. Vitamin C deficiency causes soft stools, weight loss, poor hair coat, and anorexia. Gingivitis, petechiae, swollen costochondral junctions, joint pain, and hemorrhage occur later. Treat with parenteral vitamin C
C. Tibial fractures commonly occur after foot entanglement

IX. Neurology
A. Guinea pig paralysis is a progressive disorder starting with pyrexia and urinary incontinence and progressing to posterior paresis and paralysis. The cause is unknown, but is not contagious. Treat supportively
B. Head tilt may result from trauma or otitis

X. Hematology
A. Kurloff bodies are normally found in mononuclear cells as eosinophilic intracytoplasmic inclusion bodies
B. Cavian leukemia is viral in origin, death occurs quickly, and there is no treatment

Supplemental Reading

Anderson NL. Pet rodents. In SJ Birchard, RG Sherding, editors. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, pp. 1881-1909.

Quesenberry KE, Carpenter JW, eds. *Ferrets, Rabbits, and Rodents: Clinical Medicine and Surgery*. 2nd ed. St Louis, 2004, Saunders.

Seminars in Avian and Exotic Animal Medicine. Philadelphia, 1992-2007, Saunders.

58 CHAPTER

Reptiles

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GENERAL INFORMATION

Captive-born animals are often healthier and hardier than are wild-caught reptiles, especially those that have been imported from other countries.

ANATOMY AND PHYSIOLOGY

I. Body temperature
 A. Reptiles have limited ability to control their body temperature. They need to maintain their body temperature above ambient temperatures for part of the day. This is accomplished by absorbing radiant heat, burrowing into warm soil, or by laying on objects warmed by the sun
 B. Reptiles must be able to cool themselves to avoid overheating
 C. Chilled animals are at higher risk for disease, and may go into a state of torpor
 D. The environment for a reptile should contain areas of temperature at low and high ends of the preferred optimum temperature (POT) range
 E. Tropical animals do not tolerate large fluctuations in temperature; desert animals are much more tolerant

II. Skin
 A. The shell in turtles incorporates the sternum, vertebrae, ribs, and pelvis. It is metabolically active
 B. The speculum is the epithelial covering over the eye that should shed with the skin
 C. Salt glands are on the tongue or in the nose. These glands allow conservation of water by excreting excess salt. Salt is cleared by burrowing or sneezing

III. Gastrointestinal (GI) tract
 A. The developed hyoid apparatus allows for tongue motility. Do not put pressure on the ventral neck region while restraining
 B. The mouth should never be forced open as the teeth are fragile, and injuries to the mandibles are common
 C. The esophagus contains many mucous glands but is easily torn. Use liberal lubrication if performing stomach intubation
 D. The cloaca is a common chamber for the colon, ureters, and reproductive tract. Ureters empty directly into the cloaca and not the urinary bladder. Obstruction of the cloaca can affect the GI system and the genitourinary systems

IV. Respiratory system
 A. Reptiles have paired paramedian clefts in the palate which is essential for breathing
 B. Most reptiles do not have a diaphragm
 C. Tracheal rings are complete in chelonians and crocodilians, and non-cuffed endotracheal tubes should be used
 D. In most snakes, the right lung is larger than the left

V. Cardiovascular system
 A. A three-chambered heart (two atria and one ventricle) is present in most reptiles except crocodilians
 B. In lizards and snakes, a large central ventral vein is present on the ventral midline. This vein should be avoided and should not be used for venipuncture

VI. Renal system
 A. Aquatic reptiles excrete ammonia, urea, and uric acid. Terrestrial reptiles excrete uric acid
 B. Reptiles do not have a loop of Henle and therefore can only produce isosthenuric urine. If dehydrated, urates can precipitate in the nephron causing obstruction
 C. The renal portal system shunts blood from caudal tissues directly to the kidneys. Therefore, do not administer drugs that can be cleared by renal tubules in the caudal half of the body
 D. A urinary bladder is not present in all reptiles

VII. Reproductive system
 A. All reproductive organs, including the phallus, are paired (except in chelonians and crocodilians, which have a single phallus). The copulatory organs of reptiles do not contain the urethra
 B. In females, pits in the oviduct can store sperm for up to 6 years
 C. Sex determination
 1. Male snakes have longer, thicker tails to accommodate the hemipenes. Commercially available probes can also be used to probe the cloaca
 2. In tortoises, females have a flat plastron with a notched caudal region, which allows eggs to pass. Males have a concave plastron to balance on the female and also have long tails
 3. Male water turtles do not have concave plastrons, which makes sex determination more difficult

4. Male lizards become brightly colored during mating season and have developed spines, dewlaps, and horns

VIII. Other systems
- A. Snake eyes are unique and are covered by a spectacle that topical ophthalmic preparations cannot penetrate
- B. There is no external ear opening in snakes
- C. Nasolacrimal ducts connect the eye to oral cavity, and mouth infections can often result in eye infection
- D. The thyroid gland is at the base of the heart
- E. Reptiles have lymphoid aggregates but not discrete lymph nodes

HUSBANDRY

I. Caging
- A. Terrestrial reptiles
 1. Caging should be nonabrasive, escape proof, easy to clean, and of adequate size. Snakes should be able to stretch out to two thirds of their length. Lizards should have at least 6 square inches of cage per inch of body size
 2. Provide cage furniture to stimulate activity, and provide places to hide
 3. Use paper or artificial turf for cage lining. Avoid kitty litter, gravel, or corncobs. Only use sand for desert species
 4. Keep humidity low for most species
 5. Maintain a temperature gradient over the POT range
- B. Aquatic reptiles
 1. A filter system or frequent water changes are necessary
 2. Do not use an under-gravel water filter because toxins accumulate in the gravel
 3. Most need adequate basking space outside of the water
 4. Maintain appropriate water temperature
- C. Ultraviolet (UV) light is needed by herbivorous and insectivorous reptiles to synthesize vitamin D and should be provided for 8 to 10 hours per day
- D. Provide 10 to 14 hours of light and dark daily
- E. Sanitation is very important. Phenol-based cleaners such as Lysol can be toxic. Diluted bleach is safe and inexpensive. Discard porous cage items when they become soiled
- F. Do not mix species in the same enclosure
- G. Quarantine all new additions for at least 90 days

II. Nutrition
- A. Change water every 24 hours
- B. Carnivorous animals are fed whole prey, which minimizes nutritional problems. Feed freshly killed or thawed prey. Live prey can cause injury to reptiles. Freezing of prey for at least 30 days minimizes transmission of parasites
- C. Insectivores are typically fed crickets, mealworms, and inchworms. The insects should be fed an excellent diet to increase their nutritional value. Do not feed fireflies because they may be toxic
- D. Herbivores should get more than 90% of calories from plant material. Some protein should be added to the diet, but dog food, cat food, or monkey chow should not be fed because they contain high quantities of vitamin D. Avoid calcium supplements that contain phosphorus and vitamin D

EXAMINATION AND TECHNIQUES

I. Restraint
- A. Snakes. Pick up snakes mid body. Do not pick up at the head because spinal damage can result
- B. Lizards and crocodilians
 1. Restrain small lizards by grasping the caudal mandibular area
 2. Wrap the back legs in a towel to prevent scratching
 3. Tape the snout of crocodilians with duct tape
- C. Chelonians
 1. Hold by the dorsal caudal portion of the shell, which minimizes the ability of the animal to turn around and bite
 2. Always handle over a table because dropping can cause shell fractures

II. Physical examination: History is extremely important because improper husbandry is the cause of many diseases. Observe the animal's behavior before handling
- A. Oral examination
 1. In snakes and lizards, open the mouth carefully because the teeth are fragile. The jaws of snakes are easily fractured
 2. In turtles, restrain the head from the sides behind the mandibles. Avoid pressure on the ventral surface of the neck
- B. Venipuncture
 1. In lizards, snakes, and chelonians, use the tail vein
 2. In boas and pythons, blood can be collected from the buccal veins inside the mouth
 3. Collect blood from the jugular vein if possible in chelonians. The tail vein can also be used
- C. Injections (Figure 58-1)
 1. Always give injections cranial to the kidneys
 2. Administer subcutaneous (SC) fluids over the axillary region. In turtles, the skin folds around the legs can be used
 3. In snakes, give intramuscular injections in the epaxial muscles; otherwise, use the front leg muscles
 4. Intraosseous injections can be given because veins are not readily accessible
 5. Intracoelomic injections can be given if no other route is possible. Do not use this route of administration in gravid females
- D. Radiography
 1. GI transit times are longer in reptiles than in mammals
 2. Short exposure times are necessary
 3. Ultrasound is very useful

III. Anesthesia
- A. Isoflurane is the inhalation agent of choice for reptiles

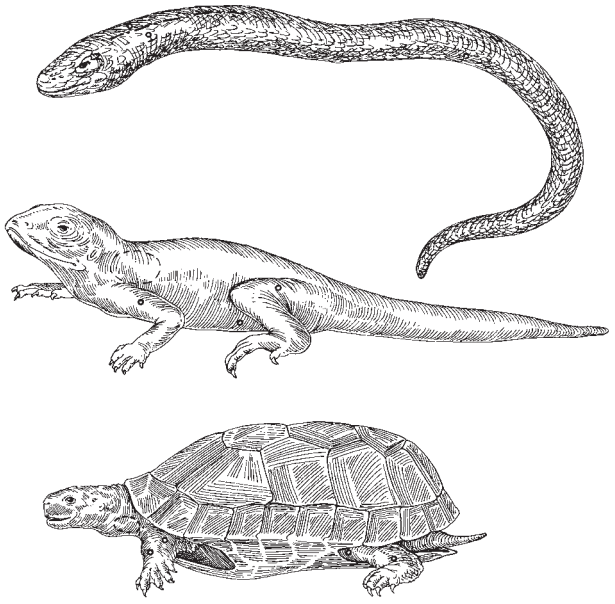


Figure 58-1 Common injection sites in a snake *(top),* lizard *(center),* and turtle *(bottom).* (From Birchard SJ, Sherding RG. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders.)

B. Propofol is a good induction agent and can be used for short procedures
C. Hypothermia should not be used as a form of anesthesia
D. Inflatable cuffs are not recommended for endotracheal tubes
E. Meloxicam has been used for analgesia

IV. Surgery
A. Reptiles cannot absorb gut sutures so use polydioxanone absorbable sutures
B. Close skin using an everting pattern so there is dermis to dermis contact

V. Drug therapy
A. Never use ivermectin in chelonians
B. Reptiles are very sensitive to glucocorticoids, so use low doses only when specifically indicated
C. Avoid injectable gentamicin; amikacin is safer
D. Be aware of species differences

DISEASES OF REPTILES

I. Bacterial
A. Most are gram negative. Anaerobic bacteria are common in lower respiratory infections
B. Reptiles are carriers of leptospirosis and *Salmonella,* which are zoonotic
1. Eradication of *Salmonella* is impossible
2. To prevent *Salmonella* shedding, minimize stress with good husbandry
3. Do not clean cages where food is prepared. Always wash hands after handling
4. Reptiles are not recommended as pets for immunocompromised people

II. Boas, pythons, lizards
A. Anorexia
1. Poor husbandry is the most common cause of anorexia
2. Rule out intestinal parasites with fecal flotation and direct smear. If there is loss of body condition, consider further diagnostics
3. Improve husbandry
a. Try different feed or prey
b. Feed when dark or quiet, and do not handle for a week after feeding
c. Monitor temperature and light cycles
4. Treat with fluids if the animal appears ill. A pharyngostomy tube can be placed to provide supplemental nutrition

B. Respiratory problems
1. Pneumonia
a. Usually secondary to poor husbandry, stomatitis, or lung parasites
b. Signs include nasal discharge, open-mouthed breathing, anorexia, and concurrent eye and mouth infections
c. Treat with antibiotics based on culture and sensitivity. Nebulization therapy may be helpful
2. Pentastomids
a. Pentastomids are arthropod parasites that look like segmented worms. They prefer lungs and SC spaces
b. Signs include dyspnea, hemoptysis, and cachexia
c. Can be seen on fecal examination or tracheal cytology
d. Ivermectin kills adult parasites but is not readily treatable. Consider euthanasia
3. Infectious stomatitis (mouth rot)
a. *Aeromonas* and *Pseudomonas* are often involved. Stomatitis is commonly secondary to poor husbandry or trauma
b. Signs include anorexia, ptyalism, oral petechiae, caseous exudates, tooth loss, osteomyelitis, concurrent eye infections, and pneumonia
c. Perform an oral examination and obtain samples for bacterial culture
d. Mild cases can be treated by an improvement in husbandry and topical iodine treatment. More aggressive therapy may be required in severe cases

C. GI problems
1. Regurgitation
a. Vomit can often look like feces, but vomit has an acid pH, whereas feces are basic
b. Excessive handling within 48 hours of a meal or low body temperature may cause regurgitation
c. Avoid handling after feeding, and provide adequate heat
2. Obstruction
a. Regurgitation, lack of feces production, abdominal distention, and anorexia are common
b. Gastrotomy or enterotomy may be necessary
3. Diarrhea
a. Caused by parasites, gram-negative bacteria, *Clostridium*, viruses, or fungi

b. Diagnose using fecal flotation, stomach wash, fecal Gram stain
c. Fenbendazole is used for most intestinal parasites. Use praziquantel if there are cestodes or trematodes. Levamisole or ivermectin may be used. Do not use ivermectin in turtles
d. For bacterial causes, use parenteral administration of antibiotics and supportive care

4. Cryptosporidium
a. Caused by *Cryptosporidium serpentis* that infects the stomach and intestines
b. Clinical signs include diarrhea, regurgitation, gastric distention, and general enteritis. Gastric disease is common in snakes, and intestinal disease is common in lizards
c. Cysts can be identified on stomach wash fluid or occasionally in feces
d. There is no effective treatment. Permanent isolation is required as animals remain carriers, and oocytes are very resistant to environmental degradation

5. Amebiasis
a. Caused by *Entamoeba invadens* and is common in snakes exposed to chelonians
b. Results in hemorrhagic gastroenteritis and liver necrosis
c. Clinical signs include anorexia, regurgitation, and hematochezia
d. Stomach wash or fecal smears contain cysts or trophozoites
e. Treat with metronidazole and supportive therapy

6. Constipation
a. Most often is caused by cool temperatures, foreign material ingestion, or abrupt dietary change
b. Signs include decreased stool production to GI obstruction. The mass of feces can be doughy to hard in the cloacal region, and the animal may be bloated
c. Try soaking for an hour in warm water two to three times daily. If this is ineffective, enemas can be given. In some cases, laparotomy may be required

7. Cloacal prolapse
a. Usually the result of straining. Pinworms are a common cause in lizards
b. Treat the underlying cause
c. Lubricate the tissue and replace with digital pressure. Suture around the cloaca to keep in place. Make sure that feces is being passed, and feed a low-residue diet for several weeks

D. Reproductive problems
1. Dystocia
a. Inability to expel eggs or fetuses
b. Usually caused by poor nutrition and poor husbandry
c. Signs include straining to lay, anorexia, or history of being overdue for laying
d. If the animal is not obstructed or ill, improve the environment
e. If eggs are not laid within a few days, then administer parenteral calcium and oxytocin every few days until eggs are expelled. Gentle manual expression may be attempted. Contents of an egg may be aspirated percutaneously. Oviductotomy is often necessary

2. Prolapsed hemipenes
a. Usually occurs after prolonged breeding and can be seen protruding from the cloaca
b. Clean and lubricate: Replace the organ, and suture around the vent to keep in place

E. Dermatologic problems
1. Mites and ticks
a. The snake mites (*Ophionyssus natricus*) are observed as small (0.5 mm) black dots on the animal or on the bedding. Many tend to be present around the spectacle, gular fold, or vent. Green iguana mites are red or gray in color
b. Ticks can be seen with their heads buried under the scales
c. Treat mites with ivermectin, but do not use ivermectin in turtles. Clean and disinfect the cage and environment. Pyrethrin flea products can be used. Treat the environment every 2 weeks for three treatments. Discard porous objects such as wood, plants, etc.
d. For ticks, spray permethrin or pyrethrin flea spray labeled safe for kittens on a cotton swab, and apply directly to the tick; then remove using forceps

2. Blister disease (vascular dermatitis)
a. Usually caused by bacterial infection but may be viral or fungal in origin. Most frequently occurs in unsanitary and high-humidity conditions
b. Causes fluid-filled vesicles or ulcerations on the ventral abdomen
c. Treat with topical dilute iodine and parenteral antibiotics. Improve sanitation

3. Thermal burns
a. Usually from exposure to a heat lamp
b. Apply diluted iodine, and use topical and parenteral antibiotics to prevent secondary bacterial infections. Fluid therapy may be needed if the burn is severe

4. Abscesses
a. Most are due to gram-negative or anaerobic bacteria
b. Caseous exudates are most common, so these do not drain well. Surgical excision is necessary
c. Leave abscesses open, flush with dilute iodine, and use topical and parenteral antibiotics

5. Gangrene
a. Gangrene may be caused by avascular necrosis, trauma, or vasculitis. Avascular necrosis occurs when shedding is incomplete and constricting bands are formed around the tail or toes
b. Amputation is usually necessary. Also treat with topical or parenteral antibiotics

6. Neoplasia
 a. Most are sarcomas or lymphoproliferative disorders. Many are associated with retroviruses
 b. Reptiles in general do not tolerate chemotherapy or radiation therapy schedules used in mammals

F. Ocular problems
1. Retained spectacles
 a. Associated with abnormal shedding of the skin and is usually due to poor husbandry (low temperature and low humidity)
 b. Clinical signs are cloudy eyes after a recent shed
 c. Soak in a warm water bath for several hours, and then remove the eye cap by rubbing with a wet cotton ball. Do not force removal. If not easily removable, then try soaking the animal immediately before the next full shed
2. Infection
 a. Infection can occur under the spectacle and is almost always associated with stomatitis
 b. The eye is cloudy with fluid under the speculum
 c. Fluid can be aspirated with a fine needle. Treat with parenteral antibiotics because topical antibiotics cannot penetrate the spectacle

G. Neuromuscular problems
1. Inclusion body disease virus
 a. Caused by a retrovirus. Transmission can be vertical, through fomites, by direct contact, or through mites
 b. Burmese pythons often only have progressive neurologic signs such as head tilt, ataxia, tremors, or coiling. In some snakes, there has been stomatitis or lymphoproliferation
 c. Inclusion bodies are seen in various tissues. The total white blood cell count may be elevated
 d. Some recover with extended supportive care but may be carriers. All new snakes should be quarantined for 90 to 180 days
2. Adenovirus
 a. In bearded dragons, acute hepatic coagulation necrosis occurs. In snakes and lizards, there is hepatitis and enteritis
 b. Neonates and young adults are typically affected. Horizontal and vertical transmission are possible
 c. Signs include seizures, tremors, lethargy, and icterus (deep golden brown oral mucous membranes and yellow sclera)
 d. Inclusion bodies can be seen in the liver and GI tract
 e. There is no specific treatment. Provide supportive care
3. Spondylitis
 a. *Salmonella* infection is most common
 b. Affected animals are stiff, and there are fused vertebrae in the spinal column
 c. Antibiotics or surgery can be attempted but rarely curative
4. Paramyxovirus
 a. Typically there is a 24- to 48-hour progressive paresis, followed by death. The chronic form is characterized by proliferative pneumonia
 b. A hemaglutination test is available for diagnosis
 c. Carriers may be common, and new snakes should be screened

H. Nutritional disorders
1. Secondary nutritional hyperparathyroidism
 a. Caused by lack of calcium or vitamin D in the diet or diets high in phosphorus. In addition, in reptiles, this can be caused by lack of adequate exposure to UV light
 b. Multiple fractures are characteristic, along with anorexia. Tremors and seizures may be present if there is hypocalcemia. Hypocalcemia may be common in bearded dragons fed a cricket diet
 c. Administer both calcium and vitamin D
 d. Dietary changes along with an increase in exposure to UV light are necessary
2. Hypervitaminosis D
 a. Most common in iguanas fed dog, cat, or monkey food as the majority of their diet
 b. Soft tissue mineralization is observed with anorexia
 c. Decrease dietary vitamin D and provide supportive care
3. Thiamine deficiency
 a. From feeding diets high in fatty fishes or muscle meat as the only food source
 b. Signs are paralysis, weakness, pulmonary edema, dehydration, blindness
 c. Treat with administration of thiamine
 d. Either feed a varied diet, or add thiamine to the feed
4. Biotin deficiency
 a. From feeding raw infertile eggs
 b. Clinical signs similar to thiamine deficiency
 c. Treat with administration of biotin
 d. Feed fertile eggs and whole-animal prey, or give a biotin supplement

I. Urinary system
1. Gout
 a. Deposition of uric acid crystals into tissues
 b. Caused by poor husbandry, diets high in protein, inadequate water consumption, or aminoglycoside antibiotics
 c. Clinical signs include organ failure, swollen joints, anorexia, sudden death
 d. Give supportive care, and increase access to water
 e. Avoid high-protein diets
2. Urolithiasis
 a. Usually in animals fed high-protein diets without access to water
 b. Perform cystotomy to remove, decrease protein content of diet, and make sure there is adequate access to water

III. Chelonians
 A. *Mycoplasma* spp.
 1. Cause upper and lower respiratory disease
 2. Treat with enrofloxacin or tylosin
 3. Give fluids and other supportive care
 4. Quarantine survivors for life as they may always be carriers
 B. Herpes virus
 1. Causes stomatitis and rhinitis
 2. Treat supportively
 3. Quarantine survivors for life as they may always be carriers
 C. Nutritional disorders
 1. Vitamin A deficiency is most common in juvenile semiaquatic turtles over 6 months of age that have usually been fed a diet of raw hamburger. Signs include squamous metaplasia of the eye, oral cavity, respiratory tract, and genitourinary tract. Treat with oral vitamin A and improve overall diet and husbandry
 2. Vitamin A toxicity is seen after parenteral administration of vitamin A. Signs include xeroderma and necrotizing dermatitis. Treat supportively (Figure 58-2)
 D. Shell diseases
 1. Trauma
 a. Stop any hemorrhage before repairing shell
 b. Clean any cracks, bandage full-thickness and wrap the shell in plastic wrap
 c. Administer fluids if needed, keep warm, give antibiotics if needed
 d. Treat minor cracks with iodine every 12 hours, topical antibiotics, and stabilize the cracks
 e. Large defects can be repaired with fiberglass or acrylic resins

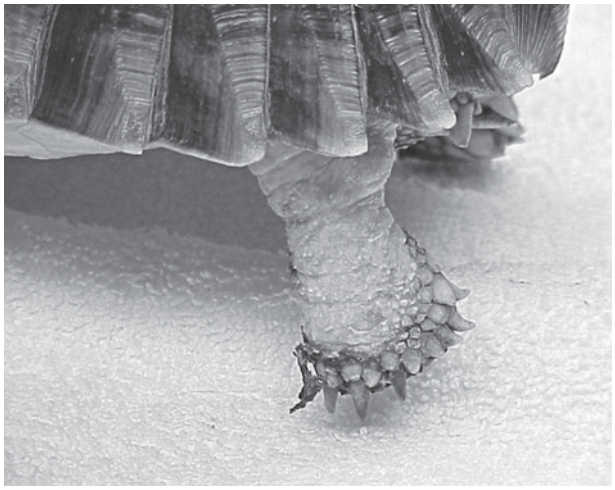


Figure 58-2 Iatrogenic hypervitaminosis A can occur as a result of oversupplementing vitamin A. In this sulcata tortoise case, the animal sloughed its skin. (From Mitchell MA, Tully TN. *Manual of Exotic Pet Practice*. St Louis, 2009, Saunders.)

 2. Rot
 a. Secondary to poor husbandry
 b. Clinical signs include petechiae, sloughing of discolored scutes, erosions, granulomatous growths. Septicemia is common
 c. Diagnosis is by examination of shell scrapings and bacterial/fungal culture
 d. Soak the shell in diluted topical iodine solution for 1 hour daily. Keep shell dry (keep out of water) for at least an hour
 e. With sterile technique, cut away dead sections of shell
 f. May need to treat with antibiotics if there are deep erosions or septicemia
 3. Pyramiding of the shell
 a. Early sign of secondary nutritional hyperparathyroidism
 b. Beak deformities may also be present
 c. May also be caused by low humidity during early growth
 E. Myiasis
 1. Flies lay eggs into wounds. Maggots hatch in 12 to 24 hours
 2. Remove maggots and treat underlying disorder. Do not use ivermectin in turtles

IV. Crocodilians
 A. Hypoglycemia
 1. Especially in stressed animals
 2. Signs of tremors, torpor, weakness, catatonia
 3. Administer glucose and improve husbandry
 B. Vitamin K deficiency
 1. Can occur if fed a marginal diet and on antibiotics. Gingival bleeding occurs early
 2. Treat with vitamin K, improve diet, discontinue antibiotics as soon as possible
 C. Caiman pox
 1. Caused by a pox virus
 2. Clinical signs are white circular lesions on the skin
 3. Quarantine; give supportive care
 D. West Nile virus
 1. Associated with acute death in Florida alligators
 2. Depression, lethargy, and neurological signs
 E. *Coccidia* spp.
 1. Causes necrotizing enteritis
 2. Diagnose with fecal swab, and treat with sulfa antibiotic

Supplemental Reading

Anderson NL, Wack RF. Basic husbandry and medicine of pet reptiles. In Birchard SJ, Sherding RG, eds. *Saunders Manual of Small Animal Practice*, 3rd ed. St Louis, 2006, Saunders, p. 1910.

Mader DR. *Reptile Medicine and Surgery,* 2nd ed. Philadelphia, 2006, Saunders.

59 CHAPTER

Zoo Animals

Patricia A. Schenck and J. Jill Heatley

AQUARIUM FISH

I. Unique anatomy
 A. Skin is thin, and there is no stratum corneum with minimal subcutaneous (SC) layer
 B. Intestinal tracts are shorter in carnivores, longer in herbivores
 C. Gills extract oxygen and function in monovalent ion regulation and nitrogenous waste excretion
 D. Ultimobranchial bodies are located near the gill slits and produce calcitonin
 E. The heart consists of the sinus venosus, atrium, ventricle, and bulbus arteriosus
 F. Fish have no bone marrow or lymph nodes
 G. Kidneys are segmented into a cranial portion with hematopoietic function and a caudal portion with excretory function
 H. The swim bladder controls buoyancy and aids in hearing
 I. Electric organs, if present, are used for communication, defense, and stunning prey

II. Water quality and filtration
 A. Water-quality problems are the major cause of captive fish illness and death
 B. Coldwater fishes require higher dissolved oxygen than do warmwater fishes
 C. Low oxygen levels can be caused by power outages that disrupt air pumps, a high fish biomass, and increased oxygen demand because of decay of a high organic load (decaying algae, decaying feed, or decaying fish)
 D. Optimal pH varies by species
 E. Salinity should be controlled
 F. Nitrogenous waste removal is one of the most important factors in fish health. Filtration can be biological (nitrifying bacteria), mechanical, or chemical. Nitrifying bacteria can take several weeks to become fully established
 G. Temperature is important; tropical species do not tolerate fluctuations in temperature

III. Nutrition
 A. Ensure that all fish are eating and that food is fresh
 B. Carotenoid pigments maintain desirable coloration of muscle (salmonids) and skin (goldfishes and koi)
 C. Fish are efficient at feed conversion (greater than 50%)
 D. Inadequate protein consumption can lead to excessive fat deposition and hepatic lipidosis
 E. Carnivorous fishes require a higher protein content in the diet

IV. Restraint
 A. Be very careful to not disrupt the scales when handling. Gloves should be worn and free of powder
 B. Coarse mesh nets should be avoided
 C. Fish can be transported in plastic bags containing one-third water and two-thirds oxygen

V. Anesthesia
 A. Withhold feed for one feeding before anesthesia
 B. Anesthesia can be administered via water, oral (PO), parenteral, or inhalation routes. Waterborne route is the most common
 C. For out-of-water procedures, continuous water flow must be provided to the gills
 D. Respiration is the most important method of monitoring anesthetic depth

VI. Diseases
 A. Viral
 1. Lymphocystis is caused by an iridovirus, and it causes hypertrophied dermal fibroblasts to form a nodule
 2. Lip fibromas are caused by retrovirus-like particles
 B. Bacterial
 1. Bacterial septicemia is common
 2. Clinical signs include lethargy, anorexia, reddened fins and oral cavity, exophthalmia, ulceration, distended fin vasculature, and disequilibrium
 3. Preferred organs for culture include kidney, and spleen. Skin lesions can also be cultured
 4. Antibiotics that are approved for use in food fish include oxytetracycline and sulfadimethoxine-ormetoprim
 5. Organisms common in freshwater fishes include *Aeromonas hydrophila, Aeromonas sobria, Pseudomonas fluorescens, Flavobacterium* spp., *Pasteurella piscicida*, and other gram-negative rods
 6. Organisms common in saltwater fishes include *Vibrio* spp. and *Photobacterium* spp. in addition to those seen in freshwater fishes
 7. Specific bacterial diseases in fish
 a. *Aeromonas salmonicida* causes furunculosis in salmonids and is a common cause of ulcerative disease of goldfishes and carp

b. *Edwardsiella tarda* causes emphysematous putrefactive disease of catfishes but has a wide host range, including humans
c. *Edwardsiella ictaluri* causes enteric septicemia in catfishes. A vaccine is available
d. *Yersinia ruckeri* causes enteric redmouth of salmonids, particularly rainbow trout. A vaccine is available
e. *Flavobacterium columnare* is associated with necrotic skin and gill lesions
f. *Renibacterium salmoninarum* causes bacterial kidney disease in salmonids
g. *Mycobacterium marinum* and other *Mycobacterium* spp. cause chronic disease in many fish species, particularly striped bass. Humans may be infected
h. *Piscirickettsia salmonis* is associated with a high mortality rate, and it causes necrosis and granulomatous inflammation of the kidneys, spleen, liver, and intestines

C. Fungal
1. Integumentary mycosis (water mold) is caused by *Saprolegnia, Achyla, Aphanomyces,* and *Leptolegmia*
2. Lesions appear fluffy in the water and slimy out of the water

D. Parasitic infections are common and amenable to treatment
1. Protozoan parasites
a. *Ichthyophthirius multifiliis* (ich) is the most common. The seawater version is caused by *Cryptocaryon irritans*. Treatment includes topical application of disinfectants or bath and dip treatments. The environment must also be treated. Increasing the temperature of the aquarium helps with treatment
b. *Amyloodinium ocellatum* causes "velvet" or "gold dust" disease and requires prolonged treatment
2. Nematode parasites include *Capillaria, Contracaecum, Eustrongyloides*, and *Anisakis* spp.
3. Cestode parasites can be prevented by not feeding live intermediate hosts as food
4. Trematode parasites can be prevented by not feeding aquatic-source live food and eliminating snail intermediate hosts
5. Crustacean parasites are usually grossly visible and can be treated by manual removal or other topical treatments

E. Noninfectious

VII. Preventive medicine
A. Quarantine
1. Quarantine for a period of 30 days for most fish
2. Maintain isolated fish in separate tanks and minimize aerosolization and fomite potential
3. Keep tanks small and easy to clean
4. Allow fish to acclimate for a few days before performing diagnostic testing
5. Species compatibility is an important consideration

B. Sanitation
1. Aquariums should be kept free of debris
2. All nets or utensils that are used between tanks should be disinfected before each use

C. Vaccination
1. Vaccines are approved for five diseases: Fibriosis, furunculosis, enteric septicemia of catfishes, columnaris, and enteric redmouth disease
2. Vaccines are administered by injection, immersion, or high-pressure spray; injection is the most effective route

MARINE MAMMALS

I. *Marine mammals* are defined as any mammal that makes the sea its home for part or all of its life. These animals include the polar bear; the marine mustelids, sea otters and marine otters; the sirenians, dugongs and manatees; the pinnepeds, sea lions, seals, and walruses; and the cetaceans, whales, dolphins, and porpoises

II. The sirenians include the manatees (Family Trichechidae) and the dugongs (Family Dugongidae). These are large, herbivorous shallow water dwelling creatures that prefer warm coastal waters and are endangered largely because of interaction with watercraft and humans
A. Manatees and dugongs are protected by a variety of regulations, including state, regional, and federal laws and international treaties
B. Classification: Kingdom Animalia, Phylum Chordata, Subphylum Vertebrata, Class Mammalia, Order Sirenia
1. Family Trichechidae
a. *Trichechus manatus* (West Indian manatee), *Trichechus manatus latirostris* (Florida manatee)
b. *Trichechus senegalenses* (West African manatee)
c. *Trichechus inunguis* (Amazonian manatee)
2. Family Dugongidae
a. *Dugong dugon* (the dugong)
b. *Hydrodamalis gigas* (Steller sea cow, hunted to extinction in the 1770s, soon after discovery)

C. Anatomy and physiology
1. General
a. Average about 10 ft long and 1200 lb as adults
b. Sparse body hair
c. Thick hide helps with buoyancy
d. Two pectoral flippers and one tail fluke
e. Respiration 2 to 3 breaths/5 min
f. Heart rate 40-60 beats/min
g. Mouth temperature 35.5° to 36° C
h. Countercurrent heat exchange and dual venous return help regulate the body temperature
i. Dense bones lack marrow cavities
2. Dental, gastrointestinal (GI)
a. Obligate herbivores, hindgut fermenters
b. Prehensile lip with vibrissae

c. Manatees lack incisors and premolars, but dugongs have incisors (tusks) and premolars
d. Manatee cheek teeth continually erupt and move forward as they wear and are thus classified as polyphydonts; however, dugong teeth are not replaced
e. GI transit 6 days
f. Equal lengths of small and large intestine, large cecum

3. Respiratory
a. Horizontal diaphragm, two independent pleural cavities, single-lobed lungs
b. Can stay submerged about 20 minutes when resting
c. Little myoglobin compared with other marine mammals; dives are shorter, shallower

4. Reproduction
a. Sexual maturity at 3 to 5 years
b. Average reproductive rate is one calf every 3 to 4 years
c. Gestation period 12 to 13 months
d. Calves are born singly and are about 4 ft long, 66 lb
e. Calves remain with their mothers up to 2 years
f. Mammary glands located behind the forelimbs; no storage sacs

D. Captive care
1. Feeding
a. Florida manatees feed on more than 60 species of plants, including turtle grass, manatee grass, water hyacinth, and hydrilla
b. Spend 6 to 8 hours/day grazing; animals in captivity are generally fed multiple times daily to simulate this grazing habit
c. Consume 7% to 15% of their body weight/day; up to 200 lb/day: Sea cow
d. Captive animals fed leafy greens such as hydroponic grass, lettuces, vegetables, high-protein monkey chow, carrots, bananas, and supplementation to balance the calcium phosphorous ration

2. Housing
a. Water depth: 1 to 4 m
b. Temperature: 23° to 30° C
c. Sanitation with ozone treatment
d. Florida manatees can be kept in salt, fresh, or brackish water
e. Second pool for treatments; can be drained

E. Restraint and anesthesia
1. Upon removal from the water, these animals can arc dorsoventrally, swing side to side, or roll
2. Chemical restraint usually unnecessary
3. Objective is to keep chin and tail flat against the surface and in line with body
4. Low metabolic rates dictate lower doses of tranquilizers, sedative, and opioids. Drugs for restraint may include the following:
a. Xylazine, medetomidine, midazolam, butorphanol
b. Reversal should be available

5. Anesthesia
a. Intubation: Nasotracheal with a cuffed foal tube
b. Mechanical ventilation at 6 breaths/min
c. General anesthesia required for limb amputation, wound debridement, deep abscess removal, and dystocia

F. Techniques
1. Intramuscular (IM) injections can be given in the caudal epaxial muscles or at the crease of the fluke
2. Catheter placement is generally in the brachial vascular bundle, an arteriovenous plexus between the radius and ulna, located on the lateral surface of the pectoral flipper

G. Clinical pathology
1. The preferred site for blood collection is the brachial vascular bundle, an arteriovenous plexus between the radius and ulna on the lateral surface of the pectoral flipper. Blood collected here will be a mixed arterial venous sample
2. A ventral midline tail arteriovenous plexus can alternatively be used for blood collection in neonates and anesthetized adults
3. Blood glucose levels should be monitored regularly in neonates
4. Circulating leukocytes are less responsive in manatees than in other marine mammals. 25,000 cell/dL is a severe leukocytosis in a manatee. More important diagnostic information in manatees is gleaned from shift in the leukocyte differential

H. Medicine and disease
1. Medication
a. PO medication administration is usually avoided
(1) Crushing action of molars may result in loss of medication
(2) May result in disruption of normal gut flora
(3) Stomach intubation usually necessary; PO or nasal routes
(4) Recommended for fluid therapy and nutritional supplementation
b. Intravenous (IV) drug administration
(1) Caution is advised with this route because of the possibility of inadvertent injection into an arteriole
(2) Long-term catheterization is difficult to maintain
c. IM drug administration
(1) Preferred method
(2) Caudal epaxial muscles
(3) Shoulder muscles
d. Pharmacokinetics of most drugs in manatees remain unknown. Most drug dosages are based on current knowledge in other species

2. Diseases
a. Infectious disease
(1) *Aeromonas* spp., *Pseudomonas* spp., *Morganella* spp., *Staphylococcus* spp., *Mycobacterium* spp. secondary to trauma
(2) Papillomavirus

b. Parasites
 (1) Clinically significant parasitism is rare
 (2) Ectoparasites on the skin; transient or commensals
 (3) Coccidia: Rare in rehabilitation animals
c. Noninfectious diseases
 (1) Cold stress: Cachexia, bacteremia, dehydration
 (a) Water temperatures below 68° F cause a complex of clinical signs and disease processes
 (b) Adult, full-size manatees tolerate cold better then small juveniles
 (c) Acute effects: Lethargy, anorexia, terminal hypothermia
 (d) Clinical signs: Shivering, cachexia, anorexia, constipation, absence of gut sounds, and flatulence
 (e) Common sequellae: Infectious bronchopneumonia, generalized infectious dermatitis, enterocolitis
 i. Various bacteria and fungi isolated
 ii. May take months of specific and supportive therapy
 (2) Brevetoxicosis-red tide
 (a) Red tides are due to dinoflagellates, including *Gymnodinium breve,* which produce neurotoxins (brevetoxins). Toxins ingested by manatees also include toxin containing ascidians (tunicates). These toxins cause hemotoxic and long-term immune effects in manatees
 (b) Clinical signs include seizure, disorientation, incoordination, hyperflexion, muscle fasciculations, flaccid paralysis, and dyspnea. Consumption coagulopathy also occurs
 (c) Treatment is symptomatic and includes fluid therapy, anti-inflammatory drugs (corticosteroids and nonsteroidal anti-inflammatories), nutritional supplementation, and devices to prevent drowning
 (3) Neoplasms are rare but include benign viral papillomas and disseminated malignant lymphoma
 (4) Human-related trauma causes about 30% of manatee death. Similar trauma also occurs in wild cetaceans and pinnepeds. Greater than 75% of manatee deaths are watercraft related; boats cause blunt and crushing injuries and cutting or shearing injuries. These injuries may result in internal hemorrhage, fractures, organ trauma, pneumothorax, and pyothorax. Entanglement in fishing line, crab trap line, and other wastes wrapped around an appendage also commonly occur. Gunshot wounds also occur. Traumatic wounds should be cleansed, debrided, and allowed to heal secondarily unless the body cavity is exposed. Water quality, fluid and nutritional support, systemic antibiotics, and topical wound care should be considered to provide optimal recovery
d. Surgery: Wounds generally heal by second intention, and surgical repair is unnecessary

III. Pinnipeds are aquatic carnivora with flippers for limbs; hence they are literally named fin (pinni) foot (ped). These animals have been present in the fossil record for more than 22 million years and are found throughout the world's seas and oceans based on water depth, temperature, ocean currents, and nutrient availability. Animals included as pinnepeds consist of three families: The earless or true seals (Phocidae) consist of 18 species; the eared seals (Otaridae) consist of nine species of fur seals and five species of sea lions; and walruses (Odobenidae) has one species
 A. Comparative anatomy
 1. Specific dental formula varies somewhat by species, but in general pinnepeds have incisors, canines, and precanines but lack molars. Sea lions are the only pinneped with external tusks
 2. Ears: Seals and walruses lack external pinnae, whereas sea lions and fur seals have external pinnae
 3. Male anatomy: Seals and walruses have testicles located outside the body cavity in a hypodermal layer of skin, whereas sea lions' testicles are located in an external scrotum. All pinnepeds have a bacula (os penis), are seasonally fertile, and testicle size along with spermatogenesis increases during the breeding season
 4. Flippers: Seals have short front flippers, hair on all flippers, and a thick nail on each of the five digits. Sea lions and fur seals have relatively long hairless front and rear flippers. Nails are vestigial and set back from the front flipper edge in the front flipper and are present as three large nails and two smaller nails on the back flipper. Walruses have five nails on each flipper, all set somewhat back from the edge of the flipper; these are larger on the rear flipper
 5. Locomotion on land: Seals are unable to rotate their hips and unable to lift weight on their hind flippers; thus, they move in a sluglike fashion on land. Sea lions, fur seals, and walruses can rotate their hips and lift weight onto their hind flipper and can walk on all four flippers, in a standard quadruped motion, on land
 6. Locomotion in water: Seals thrust from side to side in a sculling motion of their hindquarters, whereas sea lions and fur seals propel themselves through water with long fore flippers.

Walruses propel themselves through the water with a side-to-side motion of the hind flippers

B. Specialized physiology
 1. Adaptations for diving include an ability to breath hold for long periods coupled with an ability to shunt blood to vital organs, keratinized corneal epithelium, dive-induced bradycardia, as well as myoglobin-rich muscles, a higher relative blood volume (1.5 to 2 times that of a comparatively-sized mammal), and larger red blood cells (RBCs) and higher hemoglobin concentration than a comparatively-sized land mammal
 2. Adaptations for hunting underwater include large eyes adapted for vision at low-light depths and whiskers to aid in orientation and detect water current
 3. All pinnipeds share the reproductive trait of delayed implantation, which slows the zygote as it moves to the uterine horn and remains near the endometrium without attaching for an extended period, depending on the species
 a. Most pinnepeds mate once yearly in the water and give birth on land the following year. The pup stays with the mother for at least a year; gestation is approximately 1 year
 b. Walruses give birth every 2, 3, or 4 years as they age. Walrus calves are nursed for 2 years or longer

IV. Nutrition
 A. Wild diet: Herring, smelt, sardines, mackerel, squid (occasionally), clams (walruses)
 B. Captive diet usually consists of frozen fish
 1. Frozen, thawed fish is the main diet of captive pinnepeds and cetaceans. Fish should be maintained at specific conditions and carefully handled to avoid multiple nutritional diseases
 a. Fish should be kept frozen at −19° F (28° C); avoid deterioration of amino acids and unsaturated fats. Fatty fish should not be stored for longer than 6 months, and few fish can be stored for longer than 1 year
 b. Thaw under air refrigeration to decrease bacterial growth and spoilage and to avoid leeching of water-soluble vitamins
 2. Appropriate fat content is necessary to maintain weight and cause weight gain in captive animals
 3. Nutritional supplementation
 a. Thiamine, which quickly diminishes in frozen fish, is supplemented at a rate of 25 to 35 mg/kg of fish fed
 b. Sodium chloride is supplemented at a rate of 2 to 3 g/kg fish for animals housed in fresh water
 c. Vitamin E is supplemented daily based on body weight
 (1) Body weight less than 100 kg: Give 400 international units (IU) daily
 (2) Body weight 100 to 400 kg: Give 400-800 IU daily
 (3) Body weight greater than 400 kg: Give 1000 to 1200 IU daily

V. Captive housing requirements
 A. Pools should minimally measure a depth of 5 times the largest adult length, a surface area of the average adult length, squared, and a horizontal length of 1.5 times the largest adult length. Additionally, dry resting areas should measure the average adult length squared. Two or more males require two visually separated dry resting areas
 B. Hyponatremia is a recognized disease syndrome in captive animals, especially those housed in fresh water, and can result in vague neurological problems and even death. Salt tablets given PO are used to prevent this disease; see preceding nutritional supplementation section

VI. Restraint and anesthesia: These species are generally captured and restrained on land. In general, restraint and anesthesia of these species have a narrow margin of safety based on the thick blubber layer, tendency to overheat, and the dive reflex. Animals should be immobilized in cool weather or in an air-conditioned room to ameliorate these concerns. Additionally, animals should be restricted from access to deep water, and an endotracheal tube and appropriate equipment for ventilation should be available before any immobilization event is undertaken
 A. Physical restraint
 1. A herding board may be used to facilitate capture and restraint
 2. Restraint of animals weighing less than 50 kg requires one or two trained personnel. One person wraps a towel around animal's head for control while straddling the animal and grasping a towel behind the neck. The second person holds flippers against the animal's body to prevent rolling
 3. Restraint of animals 50-100 kg usually requires additional equipment including a bull pole (a long pole with a rope loop on end), net, squeeze cage, or suspension cargo nets. This method should be used only for a short procedure such as for drawing blood or injections
 4. Animals may also be trained to allow for routine procedures such as palpation, auscultation, or venipuncture
 B. Chemical restraint
 1. Diazepam can be given IM for minor nonpainful procedures such as radiography or wound care
 2. Medetomidine and ketamine may be administered IM or IV for immobilization. The dose and route vary depending on species
 3. Options of inhalational anesthesia include isoflurane for all species as well as sevoflurane for seals, but there is risk of apnea and bradycardia based on the dive reflex

VII. Diagnostic testing
 A. Auscultation of the heart should occur on the left side of the thorax, just caudal and slightly dorsal to the axillary region
 B. Lung and thoracic auscultation is best performed with the stethoscope placed behind the scapula and ventral to the attachment of the fore flipper

C. Venipuncture sites
 1. Seals: Caudal gluteal, jugular, and interdigital veins of the hind flipper, precaval vein
 2. Sea lion: Epidural intravertebral sinus (L3-L4)

D. Juveniles tend to have higher leukocyte counts than adults

E. Blood urea nitrogen (BUN) is normally higher in pinnepeds compared with most other carnivores

F. Neonates should be monitored for hypoglycemia (i.e, less than 60 mg/dL)

VIII. Infectious disease of captive and wild pinnepeds

A. Bacterial pneumonia is common in young sea lions, fur seals, harbor seals, and elephant seal pups

B. Leptospirosis occurs in northern elephant seals, harbor seals, northern fur seals, and California sea lions. Clinical disease is similar to that seen in dogs with clinical signs of depression, reluctance to move, polydipsia, pyrexia abortion, and neonatal death occurring. Severe diffuse interstitial nephritis is caused by spirochetes in the renal tubules. Animals have had titers to various serovars, and vaccination can be done in endemic areas. Appropriate precautions should be taken with animals with this zoonotic disease. Treatment is based on that in companion mammals

C. Influenza virus can cause disease in harbor seals with the clinical signs of dyspnea, lethargy, blood-stained nasal discharge, SC emphysema, and pneumonia

D. Herpesviruse and the bacteria *Mycoplasma* have been isolated from juvenile and adult seals with pneumonia. Treatment is supportive, with appropriate antibiotics, such as tetracyclines, for *Mycoplasma* spp. They have also been found in seals and sea lions with skin disease

E. Distemper viruses cause disease in seals. Pneumonia and death can occur from phocine distemper virus (PDV) and canine distemper virus (CDV). Clinical signs include ocular and nasal discharge, mucous membrane cyanosis, dyspnea, diarrhea, fever, and central nervous system (CNS) signs. Difficulty swimming and diving may occur as a result of SC emphysema of the head and neck from pulmonary damage. Treatment is based on supportive care and controlling secondary bacterial infections. No vaccine for PDV is available, but an attenuated CDV vaccine has been given to stranded seals

F. Seal pox causes skin nodules 0.5 to 1 cm in diameter; these nodules grow and ulcerate and may spread rapidly. Disease is usually self-limiting, regressing in about a month, although lesions may persist for months. This contagious disease is most common in animals that have been recently weaned or brought into captivity and is contagious to susceptible animals. Treatment is usually unnecessary, but nodules may affect an animal's ability to see or eat, and antibiotics to control secondary bacterial infection may be necessary. Humans can acquire this disease from seals

G. San Miguel sea lion virus is a calicivirus that causes vesicles on the flipper surfaces, around the lips, and on the tongue and hard palate of sea lions. These vesicles erode to ulcers, which may require treatment in case of secondary bacterial infection. This virus is not proven to cause disease in people but is serologically indistinguishable from the causative virus of vesicular exanthema of swine. Opal-eye perch also carry this virus

H. Streptothrichosis *(Dermatophilus congolensis)* (dolphin pseudopox, cutaneous dermatophilosis): This disease must be distinguished from seal pox, although simultaneous infections occur. Clinically, sharply delineated nodules occur over the entire body, and the patient may progress to death. Demonstration of the organisms on biopsy or culture necessitates systemic treatment with antibiotics of appropriate dose and extended duration

I. Clinically important parasites in pinnepeds
 1. *Uncinaria* spp. (hookworm) infestation commonly causes anemia in wild young otarids. Treatment with anthelmintics and vitamin B is indicated
 2. Lungworms include *Parafilaroides decorus*, *P. gymnurus*, and *Otostrongylus circumlitis*. Animals may have pneumonia or may be asymptomatic. Diagnosis is based on finding larvae in the feces or sputum. Treatment consists of ivermectin or fenbendazole as well as corticosteroids to lessen the inflammatory reaction of dead larvae and antibiotics to avoid secondary bacterial infection
 3. Heartworms of pinnepeds include *Dirofilaria immitis* (the companion-animal heartworm) and the parasite specific to phocids, *Acanthochelonema spirocaudata.* Cardiac insufficiency can occur from either parasite. Preventive treatment with ivermectin is recommended in heartworm-endemic regions, and louse *(Echinopthirius horridus)* removal from the rehabilitation animal is recommended to avoid vector spread of this disease
 4. Lice are commonly observed in wild pinnepeds. Most infections are species specific. Demodicosis also occurs. Treatment is as for companion mammals
 5. Infectious disease in captive pinnepeds is rarely seen but includes salmonellosis, clostridial infection, which may cause enteritis and pasteurellosis
 6. In captivity, walruses are prone to tusk infections

IX. Noninfectious disease

A. Toxicology: Wild pinnipeds are susceptible to intoxication by a variety of substances: Mercury, cadmium, lead, DDT, and inhalation of volatile hydrocarbons from oil spills. The stress of capture, transport, and holding may lower the threshold of toxicity in these species. Cetaceans and pinnepeds avoid petroleum spills and are somewhat resistant to skin toxicity. However, pinnepeds and cetaceans can develop pulmonary

hemorrhage from inhalation of volatile hydrocarbons. Treatment is based on oil removal from the skin with mild detergents and removal from the GI tract with activated charcoal and supportive therapy

B. Hyperthermia may occur in these species when the air temperature is greater than 80° F
C. Neoplasias reported in pinnipeds include transitional cell carcinoma, adenocarcinoma, squamous cell carcinoma, and melanoma
D. Foreign body ingestion occurs in pinnipeds. For a more complete discussion of foreign bodies in marine mammals, please refer to the cetacean section. The pinnipeds' pyloric sphincter is relatively small and prevents passage of foreign objects
E. Thiamine deficiency can occur in any piscivorous species (pinnipeds and cetaceans). Thiamine breaks down rapidly in frozen fish and must be supplemented. Clinical signs include CNS disturbances (ataxia, seizures, coma, and death), anorexia, and regurgitation. IM injection of thiamine results in rapid recovery. PO administration of thiamine is recommended 2 hours before food administration
F. Vitamin E deficiency is also called *steatitis* or *white-fat disease*. Improperly stored fish may be low in vitamin E and other antioxidants, necessitating supplementation. Vitamin E deficiency may be linked to hyponatremia in phocids
G. Hyponatremia is most common in phocids maintained in fresh water but can also occur in otarids and other marine mammals. This syndrome appears related to adrenal exhaustion and Addison disease, and animals can develop serum sodium of less than 140 mEq/L. Clinical signs include periodic weakness, anorexia, lethargy, incoordination, tremors, convulsions, collapse, and death. Sodium chloride infusion and corticosteroid administration are indicated in acute cases; mineralocorticoid and salt supplementation, along with serum sodium monitoring, is indicated for chronic case management. Animals maintained in fresh water may be supplemented as above with salt tablets or given access to salt water pools
H. Scombroid toxicity occurs in pinnepeds most commonly but may also occur in other marine mammals. Scombroid fish (mackerel, tuna) and other dark-fleshed fish, herring, anchovies, and pilchard spoil quickly even when frozen. A complex of substances, including histamine, are released by bacterial action. Clinical signs include anorexia, lethargy, vomiting, diarrhea, and postures associated with abdominal pain are seen. A red, inflamed mouth and or throat, urticaria, and pruritis are also evident. With removal of the offending fish, the condition is self-limiting and the animal usually resumes eating within 2 or 3 days. Treatment with antihistamines and corticosteroids may be necessary to lessen signs, especially when respiratory difficulty is evident. Avoid scombroid fish in the diet or carefully control their storage, handling, and quality to avoid this disease
I. Gastric ulcer disease in pinnepeds requires aggressive diagnosis and treatment as they are more prone to ulcerate resulting in peritonitis and death. For a more complete discussion of ulcer disease in marine mammals, please see the cetacean section
J. Trauma may occur in wild pinnepeds; for a more complete discussion, see the sirenian section
K. Ocular lesions
 1. Cataracts, corneal edema, glaucoma
 2. Wild pinnipeds have a greater incidence of ocular trauma
 3. Captive pinnipeds maintained in fresh water have a greater incidence of eye problems than those in salt water
L. Surgery
 1. Castration of captive pinnepeds is a similar procedure to other carnivores
 a. In phocids younger than 2 years, the testicle should be differentiated from the large inguinal lymph nodes
 b. In the phocids and odobenids, removal of the paradominal testes requires two incisions, caudal and lateral to the preputial opening, as well as blunt dissection to exteriorize the testes
 2. Cataract surgery is becoming common. Cataracts are removed by incising the cornea and performing an extracapsular removal of the lens
 3. In wild pinnepeds, conditions requiring surgery are relatively common and include GI foreign body and obstruction, cesarean section, prolapsed uterus, prolapsed rectum, removal of embedded foreign objects, corneal laceration, removal of infected bones in extremities, laceration repair, laparatomy, and eye enucleation

X. Cetaceans
A. Cetaceans are classified in the Kingdom Animalia, Phylum Chordata, Subphylum Vertebrata, Class Mammalia, Order Cetacea and consist of whales, dolphins, and porpoises
 1. Suborder Mysticetes (baleen whales)
 a. 13 species
 b. None in captivity in the United States
 2. Suborder Odontocetes (toothed whales)
 a. 70 species
 b. Most common species in captivity
 (1) *Tursiops truncates* (Atlantic bottlenose dolphin)
 (2) *Orcinus orca* (killer whale)
 (3) *Delphinapterus leucas* (beluga whale)
B. Anatomy
 1. This group of animals has many anatomic adaptations for living in water, which include adaptations for moving in water, thermoregulation, and aids to prey detection
 a. Body shape is elongated, streamlined, and fusiform

b. Lack external hindlimbs, external ears, external reproductive organs, and external hair
c. Pectoral fins are the equivalent of forearms in a terrestrial animal. The bones of the pectoral fin are the same as that found in terrestrial animals
d. Flukes are the two horizontally flattened divisions of the tail of a whale. No bones are found in this structure
e. Dorsal fin found in many species. This fin is dense, fibrocartilagenous, and lacks bone. This structure helps in thermoregulation and acts as a dynamic stabilizer
f. Skin: The entire epidermis turns over at a rapid rate in these species to create a smooth interface with the surrounding water
g. The blubber consists of two separate layers of fat, equal to up to 30% of body mass in many species. The skin layer is the insulatory layer, and the more internal SC layer is the first layer to be mobilized for nutrition
h. Periarterial venous rete is a vascular bundle found in the flukes, dorsal fin, and pectoral fins. A single artery is surrounded by several veins. This unique anatomic feature is used for countercurrent heat exchange
i. Multireniculate kidneys in these species consist of many small, independently functioning units called *reniculae.* The kidney roughly resembles a cluster of grapes. This kidney has more surface area than a comparably sized single-lobed kidney and allows for greater blood volume filtering, greater urine volume, and enhanced diuresis. Each lobe is a complete functional unit, and this kidney can produce urine more concentrated than salt
j. In echolocation, high-frequency signals are produced by nasal diverticulae, which are located behind the melon. The signals bounce off objects and return to the animal, which are channeled to the inner ear and transformed into neurologic signals. Echolocation is used to help find prey and identify objects in the water
k. External nares are positioned on top of the head; lack of turbinates and trachea is adapted into a goose beak, which facilitates breathing through the nares during eating

2. Dental, GI
 a. Stomach: Three chambers composed of the fore stomach, the fundic, and the pyloric chamber. The fore stomach is composed of stratified squamous epithelium. The fundic chamber is used for chemical digestion. The pyloric chamber regulates the flow of digesta
 b. Salivary glands, cecum, and gallbladder: Absent
3. Reproductive
 a. Female reproductive organs
 (1) Bicornuate uterus
 (2) Pregnancy is in the ipsilateral horn of ovulation, and ovulation usually occurs in the left ovary
 (3) Bilateral mammary slits are found on the side of the genital slit
 b. Male reproductive organs
 (1) Intra-abdominal testes
 (2) Fibroelastic penis with a sigmoid flexure
4. Comparative anatomy
 a. Mysticetes: Baleen whales
 (1) Baleen: Several individual plates that hang from the upper jaw, which filter food from large volumes of seawater. Baleen is composed of keratin
 (2) Bilaterally symmetrical blow hole
 b. Odontocetes: Toothed whales
 (1) Have teeth but do not use them to chew fish
 (2) Single external nares

C. Clinical pathology
1. Blood collection sites
 a. The caudal vascular bundle, also known as the *central fluke vein,* is the most common site for venipuncture. Blood obtained from this site is generally a mixed arteriovenous sample
 b. Other blood collection sites include peduncle, dorsal fin vein, and pectoral flipper
2. Hageman's factor: Odontocetes are deficient in factor XII and the Fletcher factor (plasma prekallikrein) of the coagulation cascade. This can make partial prothrombin time long compared with other mammals
3. RBCs of odotocetes are comparatively larger and have higher hemoglobin concentrations than terrestrial mammals
4. White blood cells of odontocetes follow a typical mammalian pattern in most disease processes. Older odontocetes tend to have higher leukocytes counts, and basophils are absent from the odontocete differential
5. The serum enzyme alkaline phosphatase tends to be higher in younger animals (calves) and can be used as a prognostic indicator. Decreased values of serum alkaline phosphatase in a clinically ill animal are associated with a poor prognosis
6. Serum sodium and chloride concentrations are generally 10% higher in odotocetes than in terrestrial mammals, likely because of the high sodium content of their diet and ingestion of seawater
7. BUN concentrations are generally higher than in terrestrial mammals
8. The erythrocyte sedimentation rate (ESR) is a clinical pathology parameter used in odontocetes to determine the presence and intensity of an inflammatory response. *ESR* is the measurement in mm of the fall of RBC in an

anticoagulant over time. Although this test is individual specific, increased values are indicators of inflammation

D. Infectious disease of cetaceans
 1. Morbilliviruses: Related to canine distemper virus. Affected animals can develop severe pulmonary and CNS lesions. Clinical signs include poor body condition, respiratory disease, bronchointerstitial pneumonia, encephalitis, and a heavy endoparasitic or ectoparasitic load. Paired titers are performed for diagnosis in captive animals. This is the most significant disease of wild cetaceans
 2. Poxvirus: Often referred to as "tattoo" lesions. Appear as black concentric rings or as black pinhole spots on the skin. Resolves without treatment. Unlike the seal form, this form is not zoonotic to humans
 3. Papillomas or fibropapillomas are "wart"-type lesions that have been found on the mucosal and cutaneous areas, such as the skin, tongue, pharynx, and penis. This disease is generally self-limiting and requires no treatment. Transmission is unknown
 4. Herpesvirus of cetaceans generally cause skin or mucosal lesions; however, in some disseminated cases, encephalitis and extensive necrotizing lesions in multiple organs result in fatality
 5. Tuberculosis (TB) is an emerging disease of marine mammals of public health significance and has been reported in a variety of wild and captive marine mammals, including dolphins, seals, and sea lions. Cutaneous and system forms of mycobacteriosis occur in marine mammals. The screening test consists of intradermal injections into the webbing of the rear flipper and is read at 48 and 72 hours. Positive responders or suspect animals require culture and identification of the organisms from tissue, tracheal washes, or feces
 6. *Erysipelothrix rhusiopathiae* is a bacteria commonly cultured in marine fish mucus, which can survive freezing and thawing. Disease caused by this bacterium is most common in juvenile unvaccinated cetaceans. However, the vaccine has caused anaphylactic reactions. Ingestion of this pathogen may cause one of two distinct disease processes. The skin form, called *rhomboid skin disease*, results in bulla formation and sloughing of the epidermis, creating a characteristic "diamond" shape. The other disease process is an acute septicemia that often is fatal without early antibiotic administration. Clinical signs may be nonspecific and include anorexia and weakness
 7. *Clostridial myositis* occurs in killer whales, pilot whales, bottlenose dolphins, California sea lions, and manatees. Clinical signs include acute swelling of and gas accumulation in the infected tissue, muscle necrosis, and severe leukocytosis. Fatality can occur. Diagnosis consists of bacterial cytology or culture and identification from the affected tissue. Systemic and local antibiotic therapy, abscess surgical drainage, and lavage form the basis for treatment. Inactivated clostridial vaccination can be given
 8. Pneumonia is the most likely differential for an ill cetacean and a common cause of death in captive marine mammals. Numerous organisms, including bacteria and fungi, can cause this disease process. Clinical signs include lethargy, anorexia, halitosis, dyspnea, pyrexia, and leukocytosis. Disease progression is commonly rapid. Diagnosis is based on tracheal samples or blow-hole culture, clinical signs, and response to therapy. Treatment consists of appropriate antibiotics, antifungals, supportive care, and correction of environmental factors. Aspergillosis has been diagnosed in a variety of cetaceans on a postmortem basis
 9. *Nasitrema* is a parasite that is a major cause of disease in wild cetaceans. This trematode affects the respiratory system and brain of odontocetes. An infection of this parasite can lead to secondary pneumonia and neurologic symptoms. Treatment is praziquantal

E. Noninfectious diseases of odontocetes
 1. Odontocetes are prone to a variety of noninfectious diseases
 2. Small intestinal torsion usually occurs at the root of the mesentery. Predisposing factors of disease are unknown
 3. Fatal thrombocytopenia and neutropenia can occur in cetaceans with the use of sulfa-containing antibiotics. Cetaceans should always be supplemented with folic acid or leucovoran when any sulfa-containing antibiotic is administered
 4. Gastric ulcers are common in captive cetaceans and can occur with the administration of nonsteroidal antiinflammatories or with corticosteroids. Ulcers of cetaceans may occur in the stomach or in the pylorus or duodenum, causing more severe clinical disease. Parasites, histamine of spoiled fish, environmental stressors, and other stressors can all contribute to ulcer formation. Clinical signs include anorexia, regurgitation, lethargy, abdominal pain, and pallor. Anemia and leukocytosis may also occur. Diagnosis may be by visualization of the lesion with endoscopy of cytologic examination of gastric washes for intact mammalian RBCs. Treatment is based on standard mammalian regimens and may include histamine-type 2 blockers, sucralfate, antacids, multiple antibiotics, fluid therapy, and frequent small meals
 5. Abscesses of the dental pulp and alveolus are common
 6. Scoliosis and lordosis are spinal abnormalities that occur in stranded dolphins. These animals are initially weak and usually have limited mobility. Physical therapy can prevent or correct this condition

7. Renal calculi may occur in cetaceans, which may or may not show clinical signs of hematuria and anuria. Echo-dense radiolucent stones may be found in the collecting ducts of the kidney. Diagnosis may be supported by a finding of an elevated uric-acid creatinine ratio from a patient, which has been fasted for greater than 12 hours
8. Oil exposure can occur on cetaceans. For a more complete overview of the disease and treatment options, please see the pinneped section. Cetaceans appear relatively resistant to oil exposure based on avoidance and behaviors and decreased susceptibility to toxicity. Baleen fouling of mysticetes with oil generally resolves in 24 to 36 hours
9. Zinc toxicity may occur in captive cetaceans after ingestion of pennies or other coins. Anemia, hepatopathy, and CNS disorders may result
10. Foreign-body obstruction is common in captive and wild cetaceans but may also occur in sirenia and pinnepeds. However, rocks are commonly found in the stomachs of healthy animals. Many foreign bodies are a result of human-related pollution, such as plastic bags, firecrackers, fish hooks, and other objects. The opening to the second compartment of the cetacean stomach is small, causing foreign objects to remain in the first compartment. Animals may regurgitate the foreign object. Clinical signs may vary from none to anorexia, regurgitation, or lethargy. Diagnosis can be made by observance of the animal swallowing the object, radiography of small animals, palpation of the esophagus in small cetaceans, or endoscopy. Gastroscopy is usually indicated for removal of foreign objects. Avoidance of ingestion of foreign objects is recommended by limited human exposure to captive animal holding areas and by training animals to retrieve as a replacement behavior for swallowing foreign objects
11. Trauma may occur in wild cetaceans. For a more complete discussion, please see the sirenian section

F. Surgery of odontocetes: Surgery of odontocetes is limited to dentistry, abscess treatment, wound care, mandibular or maxillary fracture repair, and endoscopic or laparoscopic exploration or biopsy

G. Anesthesia and chemical restraint of cetaceans
1. Anesthetic agents used in these species include isoflurane, diazepam, midazolam, ketamine, medetomidine, thiopental, and propofol
2. Large equine endotracheal tubes are necessary for intubation of adult cetaceans
3. The trachea bifurcates proximally in many cetaceans; mainstem bronchial intubation is avoided by checking the length of insertion of the endotracheal tube

PRIMATES

I. Prosimians
A. Anatomyand physiology
1. Prosimians include lemurs, lorises, pottos, galagos, and tarsiers
2. Prosimians are present in Africa, Asia, and Madagascar
3. Most prosimians are nocturnal. Sifakas and indriidae are diurnal
4. Lorises and pottos are slow moving. Tarsiers and indriidae are vertical climbers and leapers
5. They have a low metabolic rate compared with other primates

B. Feeding
1. Some species have very specific dietary requirements. Golden bamboo lemurs have developed the ability to detoxify bamboo that is high in cyanide. Lemurs can consume leaves that are high in alkaloids. Some lemurs have adapted for nectar or gum feeding
2. Lemurs can be sensitive to vitamin D and maintain low levels
3. Lemurs also have a high incidence of diabetes mellitus, which may be dietary related
4. Most prosimians do not have a requirement for vitamin C
5. The most common problem of lorises is obesity

C. Diseases
1. Bacterial
a. GI disease can be caused by *Yersinia enterocolitica*, *Campylobacter fetus jejuni*, *Salmonella typhimurium*, and *Escherichia coli*
b. Pneumonia is not common in lemurs with good management. *Klebsiella pneumoniae* can cause pneumonia in stressed animals
c. *Proteus*, *Klebsiella*, *Yersinia*, and *Pseudomonas* spp. have been implicated in septicemia
d. The incidence of TB in prosimians is low
2. Fungal: Cutaneous mycoses are rare
3. Viral
a. Herpesvirus has been associated with meningoencephalitis
b. Viral encephalitis is rare
4. Parasitic
a. GI parasites are a common cause of diarrhea. Protozoal parasites are more common and include *Entamoeba*, *Trichomonas*, *Giardia*, and *Balantidium* spp.
b. Some lemurs are sensitive to *Toxoplasma gondii* infection
c. Malarial parasites have been identified in some blood smears
5. Noninfectious
a. Trichobezoars occur in captive lemurs and may need to be surgically removed
b. Hemochromatosis (iron storage disease) occurs in lemurs in captivity
c. Pleural effusions have occurred in lemurs
d. In black lemurs, progressive renal failure has been described in association with a familial bone disease

e. Renal degeneration is a common cause of mortality in old prosimians
f. Spongiform encephalopathy has been reported in captive lemurs
g. Pectus excavatum is inherited as an autosomal dominant gene

6. Reproductive
a. Prosimians have a bicornuate uterus
b. Most species of lemurs have seasonal reproductive cycles
c. Galagos (bush babies) usually have triplets

II. Other primates (excluding great apes)
A. Anatomy and physiology
1. There are 13 families of primates
2. New World primates: The Callitrichidae and Cebidae. These primates are arboreal and have prehensile tails
3. 284 species of primates are considered endangered
4. Most primates have five digits with nails, although the Callitrichidae have claws
5. Primates have color vision
6. As vision increases, the sense of smell decreases and the nose becomes shorter
7. The face is usually naked, but some have a beard. True sweat glands are present
8. Air sacs are present in some for improved vocalization. The hyoid apparatus is modified in the howler monkey to produce a resonant sound
9. New World primates have estrous cycles and do not menstruate. Old World Primates menstruate

B. Housing
1. Species vary greatly in size, and adequate space is required for natural behaviors
2. Environmental enrichment is necessary

C. Nutrition
1. Most primates are omnivores, eating plants, fruits, nuts, insects, and small invertebrates
2. Some primates are folivorous (colobines, *Presbytis*, and howler monkeys) and eat only foliage. These primates require diets very high in fiber
3. The Old World primates (Cercopithecidae) are mostly herbivores, but some are carnivores (baboons). These primates have cheek pouches
4. Primates eat 2% to 4% of their body weight daily. Many primates are fed a variety of food items in the hopes that they will eat a balanced diet, but this is not always the case, and obesity, nutritional secondary hyperparathyroidism, and hypoproteinemia are common problems. Certain foodstuffs should be restricted (fruits), with a canned diet or diet biscuit
5. Primates require vitamin C
6. New World primates require vitamin D if they have minimal exposure to sunlight. Marmosets have a particularly high requirement. Insects that are fed should be eating a high-calcium diet for a few days so that they are enriched with calcium
7. Vitamin E deficiency has been associated with anemia

D. Restraint
1. Smaller primates can be restrained by hand, whereas larger primates may require anesthesia
2. Some primates can be trained for minor procedures

E. Diseases
1. Infectious
a. Salmonellosis, shigellosis, yersiniosis, and campylobacteriosis are common diarrheal diseases
b. *Mycobacteria*, streptococcus, *Bordetella*, *Klebsiella*, adenoviruses, paramyxoviruses, and measles are common causes of pneumonia. TB is the most important, and all primates should be tested for TB
c. Macaques are carriers of herpesvirus B. In humans, this disease is often fatal

2. Parasitic
a. Many parasites that infect nonhuman primates also infect humans
b. Primate specimens should be considered biohazards

3. Miscellaneous
a. Rectal prolapse occurs subsequent to diarrhea
b. Lion-tailed macaque males have a predisposition to inguinal hernia
c. Acute gastric dilation occurs, usually from *Clostridium perfringens*
d. The main postoperative complication in primates is picking at sutures
e. Male adult primates have long, sharp canine teeth that can inflict considerable damage to others. Canine teeth can be filed down to a blunt tip; a root canal or pulpectomy should be performed
f. Hypoglycemia occurs in small primates that are anorexic
g. Goeldi marmosets are predisposed to progressive nephropathy
h. Iron storage disease is a major problem in Saki monkeys
i. Primates are predisposed to GI adenocarcinomas
j. Celebes macaques are genetically predisposed to diabetes mellitus

III. Great Apes
A. Anatomy
1. A unique feature of the great apes is that they have laryngeal sacs that communicate with the laryngeal ventricles
2. Their arms are longer than their legs
3. They have two pectoral teats

B. Housing
1. Great apes need room to be social but with adequate space
2. Their environment needs enrichment
3. They need heated quarters when temperatures drop below 7° C

C. Nutrition
 1. Great apes require exogenous vitamin C
 2. All great apes are predominantly herbivores. Gorillas and orangutans are exclusively herbivores
D. Restraint
 1. Squeeze cages can be used
 2. Many apes can be trained to be still for a number of minor procedures or physical examination
E. Diseases
 1. Viral
 a. Ebola virus can infect chimpanzees
 b. Simian immunodeficiency virus (SIV) occurs in chimpanzees. One lineage of SIV may be the origin for human immunodeficiency virus-1
 c. T-cell lymphoma in a gorilla has been linked to simian T-lymphotrophic virus infection, and non-Hodgkin's lymphoma in a gorilla has been linked to human T-cell leukemia virus infection
 d. Hepatitis A can infect chimpanzees, gorillas, and orangutans. Chimpanzees are susceptible to the human hepatitis A
 e. Hepatitis B occurs in chimpanzees, gorillas, and orangutans, although it differs from the human strain
 f. Human herpesvirus 1 can infect chimpanzees and gorillas
 2. Bacterial
 a. *Streptococcus pneumoniae* is the most common cause of bacterial meningitis in great apes
 b. TB has become an uncommon disease of great apes because of TB testing
 c. Laryngeal air sacculitis occurs following chronic respiratory infection. Fatal pneumonia may develop
 d. *Bordetella pertussis* (whooping cough) has been reported in chimps
 e. Antibiotics used in great apes are the same as used in human medicine
 f. Of mycotic infections, candidiasis and coccidioidomycosis are most significant
 3. Parasitic
 a. *Strongyloides, Entamoeba*, and *Balantidium* are the most problematic parasites in great ape colonies
 b. *Strongyloides* may cause significant morbidity and mortality
 4. Cardiovascular
 a. Cardiovascular diseases are a common cause of morbidity and mortality in great apes
 b. The most common cardiovascular diseases are fibrosing cardiomyopathy and aortic dissection
 5. Musculoskeletal
 a. Rickets have been reported and can be prevented with proper vitamin D supplementation and exposure to ultraviolet (UV) light
 b. Arthritis is not uncommon
 6. Neoplasia: Oral papilloma in chimpanzees is the most common neoplasia in great apes
 7. Dental diseases: Exposed root canals from trauma are common in great apes
 8. Endocrine: Hypothyroidism and diabetes mellitus have been reported

DISEASES COMMON TO MULTIPLE SPECIES

I. *Salmonella, Shigella*
 A. Both *Salmonella* and *Shigella* spp. are members of Enterobacteriaceae
 B. Epidemiology
 1. *Salmonella* affect most vertebrates
 2. Poultry and reptiles are typical carriers. About 90% of reptiles carry *Salmonella* with no clinical signs
 3. Stress, transport, changes in husbandry, environment, diet, and dehydration can cause activation of *Salmonella*
 4. The natural host for *Shigella* is primates. Dogs are occasionally infected. *Shigella* is highly contagious, and a very low dose is needed for infection
 5. Both *Salmonella* and *Shigella* remain in the environment for prolonged periods and are resistant to drying and freezing. Both are killed by chlorination and most disinfectants
 C. Transmission is typically via ingestion of contaminated food or water or by contact with infected animals
 D. Clinical signs
 1. *Salmonella* colonizes in the small intestine, and *Shigella* colonizes in the large intestine
 2. Typical clinical signs include gastroenteritis with vomiting and diarrhea
 3. In young and old animals or immunosuppressed animals, there may be septicemia with multiple organ damage that can lead to death
 4. *Salmonella* infections can become chronic. *Shigella* infections are usually self-limiting or fatal
 E. Diagnosis is by culture of fecal material
 F. Treatment
 1. Supportive treatment is used for mild infections
 2. Antibiotics are used in severe infections, but antibiotics do not eliminate *Salmonella*, and there is a high risk of creating carrier individuals
 G. Control
 1. Routine fecal cultures may be performed to identify carriers
 2. Stress should be kept to a minimum to prevent outbreaks of disease in those that are carriers

II. TB
 A. Introduction
 1. Outbreaks in zoos continue, although the incidence is currently low
 2. Has the potential to cause significant mortality in many species

3. Cells have a thick, waxy envelope and are acid-fast positive

B. *Mycobacterium tuberculosis*
1. Infection is of great concern because of the zoonotic potential of transmission from animals to humans and humans to animals
2. This is primarily a human pathogen, causing classic TB. It commonly infects the lower respiratory tract; signs include anorexia, chronic productive cough, chest pain, low-grade fever, night sweats, and weight loss. Many infections become latent but remain infective to others
3. Can cause severe morbidity and mortality in nonhuman primates. Asian Old World primates such as rhesus monkeys are particularly susceptible. African Old World primates (such as baboons and great apes) have a more slowly progressive disease. Infection in South American primates is rare. Intradermal skin testing is used, but some species are overreactive (such as the orangutan) and have a high percentage of false positives. Prevention involves keeping nonhuman primates separated from infected humans. Glass-walled enclosures are often used to prevent the aerosol spread
4. Seals and sea lions can also be infected
5. TB can affect Asian elephants but is rare in African elephants. It appears to occur only in captivity and is probably the result of exposure to infected humans. Culture of respiratory secretions is best for diagnosis
6. Cases have been reported in psittacines

C. *Mycobacterium bovis*
1. Closely related to *Mycobacterium tuberculosis*
2. Primarily a pathogen of bovine species (cattle, buffalo, and bison). Clinical signs range from no signs to pulmonary disease and chronic debilitation. Granulomas develop in pulmonary tissues, pleura, and lymph nodes of the head, neck, and thoracic cavity. The disease spreads throughout a herd before clinical signs are noted
3. Transmission is via aerosolization
4. Intradermal skin test is the primary screening method, although it may be difficult to interpret in captive species
5. Control relies on early detection and removal of infected animals
6. *M. bovis* infection has been reported in cervids, antelopes, camelids, perissodactylids, nonhuman primates, carnivores (badgers, ferrets, fennec fox, leopard, lion, tiger), marsupials, and humans

D. *Mycobacterium avium-intracellulare*
1. Primarily a pathogen of birds and can affect all avian species
2. Source of infection is environmental or by contact with an infected bird. The organism can survive in the environment for years
3. Clinical presentation is of chronic wasting, lethargy and weakness. Granulomas are seen in the liver, spleen, GI tract, and bone
4. Also an important cause of death in tree kangaroos. The organism can also infect immunocompromised humans

E. *M. avium* ssp. *paratuberculosis* (Johne disease)
1. Primarily affects ruminants and camelids
2. Causes chronic, fatal intestinal disease
3. Clinical signs include weight loss, poor hair coat, and diarrhea
4. Nondomestic ruminants are susceptible
5. Transmission is via ingestion of contaminated food or water. The organism can live in the environment for over a year
6. This organism may be a causative agent of Crohn disease in humans

F. *Mycobacterium leprae*
1. Causes leprosy in humans, nonhuman primates (chimpanzees, mangabeys, and cynomolgus macaques), and armadillos
2. In nonhuman primates, clinical signs include chronic nasal discharge, epidermal erosions, and nodules on the face, lips, eyebrows, chin, and scrotum

G. *Mycobacterium marinum*
1. Primary pathogen in captive fishes. Has been reported in more than 150 species of freshwater and saltwater fishes
2. Signs include exophthalmia, weight loss, dermal ulcers, and ascites. It is eventually fatal
3. Transmission is from ingestion of contaminated food or water
4. Affects humans; causes a granuloma of the skin (fish handler's disease or aquarist finger)

H. *Mycobacterium genavense*
1. First isolated from immunocompromised humans, but also infects birds
2. Affected birds have weight loss, muscle wasting, respiratory disease, and diarrhea
3. Difficult to isolate on culture

III. Anthrax

A. The cause is *Bacillus anthracis* which is aerobic and spore-forming

B. Epidemiology
1. Primarily a disease of mammals; in zoos, the disease is most often restricted to carnivores. In the wild, the disease usually affects herbivores
2. Spores remain in the environment, either in dead carcasses or in soil in livestock burial places. Spores have been documented to be viable for more than 200 years
3. Anthrax has a large potential for biological warfare
4. In captivity, anthrax infection is the result of ingestion of contaminated meat
5. In the wild, scavengers can open dead carcasses and spread spores over large areas

C. Pathogenesis
1. Infection is acquired through ingestion of spores. The spores germinate in the pharynx or intestinal tract and produce toxin
2. They then travel to regional lymph nodes and the reticuloendothelial system, and bacteremia develops

D. Diagnosis
1. Most ruminants experience sudden death without prior signs of illness
2. Omnivores, carnivores, and immunized animals develop edematous swelling of the face, throat, and neck. It may progress to a more acute form, or animals may recover
3. Postmortem, the most common lesions are edema, hemorrhage, and necrosis
4. Diagnostic testing includes examining stained blood smears, culture, and polymerase chain reaction (PCR) or enzyme-linked immunosorbent assay (ELISA) testing
5. All causes of sudden death and localized SC edematous swelling resemble anthrax

E. Management and therapy
1. Reportable disease
2. Effective surveillance
3. Quarantine
4. Vaccination of cattle yearly in a high-risk area
5. Vaccination of free-ranging wildlife
6. Burn known anthrax-contaminated vegetation

IV. Leptospirosis

A. Causes
1. Occurs worldwide in most mammals
2. Leptospires are gram-negative aerobes that do not stain well and require specialized growth medium
3. A number of different serovars occur in different geographic areas and have different maintenance hosts
4. Leptospires invade the body after they penetrate mucous membranes or damaged skin. They then get into the bloodstream (after 4 to 20 days) and circulate in the blood for about a week. They can replicate in any tissue, including liver, kidneys, lungs, CNS, and genital tract. Leptospires remain in renal tubules, and urinary shedding is long-term in maintenance hosts

B. Transmission
1. Involves direct or indirect contact with infected urine, placental fluids, or milk. It can also be transmitted transplacentally
2. Organisms can survive in the environment for several months, especially in damp areas that are protected from sunlight and temperate. Leptospirosis occurs most frequently in spring, autumn, and early winter

C. Clinical signs
1. Signs include fever, anorexia, depression, vomiting, diarrhea, icterus, renal failure, abortion, hemoglobinuria, and death
2. Subclinical infections may be common
3. Most zoo animals are infected via exposure to infected urine that has contaminated the environment or food

D. Diagnosis
1. Serum antibodies against leptospiral serovars are detected with a microscopic agglutination test. A fourfold rise in titer is considered diagnostic
2. Vaccination in zoo animals can complicate the interpretation of titers

E. Management and therapy
1. Prevention is aimed at minimizing exposure, and vaccination
2. Killed vaccines are available for some serovars in domestic animals; the efficacy of vaccines in zoo animals is unknown
3. Tetracyclines have been used for therapy

V. Aeromonas, Pseudomoniasis

A. Causes
1. Pseudomonads include *Pseudomonas aeruginosa, P. flourescens*, and *P. putida*. *P. aeruginosa* is the most important
2. Aeromonads include *Aeromonas hydrophila, A. caviae, A. sobria*, and *A. salmonicida*. *A. hydrophila* has the most clinical significance. *A. salmoncida* affects fish

B. Epidemiology
1. Pseudomoniasis is underreported in zoo species
2. *P. aeruginosa* is an opportunistic pathogen in birds; waterfowl, penguins, and psittacines are particularly susceptible. Contaminated drinking water is a common source of infection
3. *P. aeruginosa* is common in reptiles, causing dermatitis, stomatitis, and pneumonia. Infectious stomatitis is common in snakes
4. Aeromonads are significant opportunists and cause diarrhea and enteritis in mammals including cattle, suckling camels, horses, and humans. They can cause septicemia in lynx, rabbits, and pinnipeds
5. Aeromonas is uncommon in birds but a common opportunist in reptiles. *A. hydrophila* causes sepsis in alligators and pneumonia in snakes. In amphibians, it is associated with "red leg"

C. Infection and transmission
1. These organisms are found in the soil and water and are considered normal flora of the intestinal tract
2. Contaminated drinking water, tank water, and bedding are common sources of infection
3. Cutaneous mites can transmit these organisms in snakes
4. Humans can develop regional *Aeromonas* infections from bites from opossums, snakes, and crocodiles; from medicinal leeches; and following punctures from catfish spines
5. Aquatic environments with many bird visitors can have a high fecal load with degradation of water quality

D. Diagnosis
1. Based on clinical signs and aerobic culture
2. In reptiles, clinical signs include drooling, open mouth, ventral edema, and swelling and crusting of the oral mucous membranes. Pneumonia is a frequent complication
3. In amphibians, aeromoniasis clinical signs include pallor, petechiae, lethargy, anorexia, and generalized edema
4. Postmortem, there are no pathognomonic lesions

E. Management and therapy
1. The appropriate antibiotic should be chosen from culture and sensitivity results
2. Underlying conditions should be identified

F. Prevention
1. No vaccines available
2. Good husbandry is most important: Maintain good water quality and temperature of the environment; avoid overcrowding, trauma, and stress

VI. Plague

A. Cause
1. *Yersinia pestis*, a member of the Enterobacteriaceae family
2. It has a "safety pin" appearance when stained
3. It is killed by sunlight, drying, heat, and most disinfectants
4. Plague is a reportable disease

B. Epidemiology
1. Affects many species; natural hosts are rodents and associated fleas
2. Enzootic hosts (with some resistance to plague) include California voles, grasshopper mice, and deer mice
3. Epizootic hosts (with large-scale mortality) include prairie dogs and squirrels
4. Nonrodent hosts that are resistant include coyotes and badgers
5. Susceptible nonrodent hosts include primates, felids (including domestic cats, bobcats, and mountain lions), ferrets, polecats, and lagomorphs

C. Transmission
1. Plague in captive animals is rare but can occur if infected animals are brought into a captive facility. Prairie dogs or ferrets that are wild-caught should be quarantined for a minimum of 2 weeks. Wild-caught rodents are typically treated with topical insecticide sprays
2. Oral transmission readily occurs if animals ingest infected prey
3. Animals may also be infected from the bite of an infected flea

D. Clinical signs
1. There are three forms: Bubonic, septicemic, and pneumonic
2. Bubonic plague occurs after local infection through a flea bite or abrasion in the skin. There is focal acute inflammation, and lymph nodes become swollen, necrotic, and inflamed, (a bubo). Secondary septicemia may occur
3. Pneumonic plague is rare and occurs after inhalation of aerosolized *Y. pestis* into the lung
4. Clinical signs include anorexia, depression, high fever, and dehydration. In bubonic plague, painful, swollen lymph nodes are present. With flea bites, lymph nodes in the axillary or inguinal region are most commonly enlarged. In subacute cases, lymph nodes may break and drain through the skin

E. Diagnosis
1. Antemortem diagnosis is via serology or culture. An ELISA test can be used to detect F_1 antigen, and PCR assays have been developed. Serology may be conducted on nonrodent species for surveillance
2. Postmortem diagnosis: Regional lymphadenopathy is common in bubonic plague. Microscopic lesions are characterized by large numbers of gram-negative bacteria in lumens of vessels or in perivascular locations. Direct fluorescent antibody staining for the F_1 antigen is a specific test for plague
3. In the field, a rapid loss of animal activity in the absence of poisoning (in geographic areas of plague) suggests plague. Dead rodents should be tested, along with collected fleas

F. Differential diagnosis: Acute bacterial infections causing lymphadenopathy include tularemia, septicemic pasteurellosis, and *Y. pseudotuberculosis*

G. Management
1. Prevent human exposure and infection. Most disinfectants readily kill plague
2. Streptomycin is the antibiotic of choice
3. Prevent wild rodents from invading housing structures
4. There has been little success with attempts to control fleas in the environment of free-roaming rodents

VII. Colibacillosis

A. Etiology
1. *Escherichia coli* are normal intestinal flora in many species. Enterotoxigenic and enteropathogenic strains have been described in animals
2. *E. coli* are short gram-negative rods
3. *E. coli* becomes established within the intestinal tract within days after birth
4. Disease is most often reported in domestic or captive animals

B. Pathogenesis
1. Enteric disease is common in mammals, and colonization results in enterocytic death, invasion, and sepsis
2. Septicemic colibacillosis often occurs in newborns or in immunocompromised hosts.

C. Diagnosis
1. Clinical signs are suggestive. Culture may help isolate. PCR techniques may be useful in some species
2. Lesions may be subtle, with intestinal distention with fluid. There may be necrotic or hemorrhagic lesions in the intestine. Sepsis may be present.

D. Prevention and control
1. Enteric bacteria can be transmitted by personnel, instruments, and on other objects. Good hygiene is critical for prevention. Control of humidity, environmental contamination, and ventilation are important for prevention in avian species
2. Medication of drinking water in turkeys, ducks, and quail can reduce morbidity and mortality
3. The use of antibiotics to treat can lead to antimicrobial resistance
4. Vaccines are being investigated

VIII. Clostridia
A. GI clostridial diseases
1. *Clostridium perfringens*
a. The most important enteric clostridial pathogen. Toxins produced are all exotoxins and can also be endotoxins if they cause disease in the intestine
b. *C. perfringens* type A is a normal inhabitant of the intestinal tract. It can cause necrotizing or hemorrhagic enteritis in mammals and birds. Type A produces α-toxin and causes "yellow lamb disease" in lambs as a result of hemolytic disease
c. *C. perfringens* type B causes necrotizing enteritis in young lambs in Great Britain and South Africa
d. *C. perfringens* type C typically infects neonates and occurs in calves, lambs, foals, piglets, chickens, waterfowl, psittacines, ratites, and humans. Type C β-toxin causes intestinal necrosis and hemorrhage
e. *C. perfringens* Type D is normal in ruminants in low numbers. Called "overeating disease" because it can be associated with animals on lush pasture or receiving large amounts of grain. Type D strains produce ϵ-toxin, which acts on endothelial cells. Clinical signs are related to increased vascular permeability in the brain, heart, and lungs. Type D is a true enterotoxemia. Sudden death is common
f. Treatment is usually not an option because of sudden death. If chronic, long-term antibiotics and a high-fiber diet can help. Prevention is to maintain good hygiene and eliminate stress. Probiotics such as *Lactobacillus* may be helpful in prevention
2. *Clostridium colinum*
a. Causes ulcerative enteritis in gallinaceous birds, particularly quail and ratites
b. Affects birds 1 to 3 months of age. Clinical signs range from sudden death to watery droppings in acute disease or dull, ruffled feathers and emaciation in chronic cases
c. Predisposing factors include stress, poor hygiene, and overcrowding
d. Streptomycin or bacitracin can be used prophylactically in water or food. Prevention is by minimizing stress and maintaining good hygiene
3. *Clostridium septicum* (braxy)
a. Causes hemorrhagic, necrotizing abomasitis in young ruminants
b. Cold milk or feed initiates mucosal injury and allows invasion
B. Antibiotic-associated clostridial disease
1. *Clostridium difficile*
a. Causes antibiotic-associated diarrhea and pseudomembranous colitis in mammals and birds. It has also been isolated from snakes and lizards
b. Alteration of intestinal flora by antibiotics allows colonization by *C. difficile*
c. Clinical signs usually start within a week of starting antibiotics. Signs include watery diarrhea and dehydration
d. If mild, withdrawal of antibiotics may be all that is necessary. Metronidazole has been used for more severe cases
e. Penicillins, tetracyclines, macrolides, β-lactams, cephalosporins, and lincosamides are most often associated with *C. difficile* infection
2. *Clostridium spiroforme*
a. Causes diarrheal disease in weaned rabbits. Diarrhea is acute with rapid progression to death
b. Infection is probably acquired from the environment
c. Antibiotic therapy or a change in cecal flora associated with weaning is a predisposing factor
d. Metronidazole is an effective therapy
C. Hepatic clostridial diseases
1. *Clostridium piliforme*
a. Affects many mammals but rare in birds
b. Stress and poor husbandry play a role in disease
c. Sudden death is the most common presentation; there may be severe watery diarrhea
d. Tetracyclines can be effective during outbreaks. Prevention is by minimizing stress and maintaining good husbandry
2. *Clostridium novyi* type B (black disease)
a. Infection is by ingestion of spores
b. Larval migration of parasites to the liver can induce disease
c. Affected animals are usually found dead with no clinical signs. SC vessels are engorged with blood, which can give the carcass a black appearance
d. Control of snails can help reduce exposure to the intermediate host
3. *Clostridium haemolyticum* (bacillary hemoglobinuria)
a. Epidemiology and pathogenesis are similar to *Clostridium novyi*
b. *C. haemolyticum* produces large amounts of β-toxin, which results in acute hemolytic anemia. Affected animals are found dead and have sudden onset of hemolysis
D. Neuromuscular toxicoses
1. *Clostridium botulinum*
a. Causes flaccid paralysis in avians and mammals
b. Outbreaks occur from contamination of feed or water. Scavenger birds can be vectors
c. Shaker foal syndrome occurs when *C. botulinum* spores produce toxin in the intestinal tract in foals
2. *Clostridium tetani*
a. Ubiquitous in the environment. When present in necrotic wounds, surgical sites, or such sites, it produces a neurotoxin (tetanospasmin) which causes clinical signs

b. Carnivores and bovids are more resistant than equids and small ruminants. There are no reports in birds or reptiles
c. Clinical signs include spasms and spastic paralysis
d. Treatment involves providing muscle relaxation, providing deep bedding, eliminating the organism by debridement or flushing, giving tetanus antitoxin, providing supportive care, and vaccinating with tetanus toxoid
e. Prevention is via vaccination with tetanus toxoid and eliminating hazards that could result in penetrating wounds

E. Myositis, cellulitis, and gangrene
1. Cause: *Clostridium perfringens* type A, *C. septicum, C. sordelli, C. chauvoei*, and *C. novyi* type B
2. These agents are ubiquitous in the environment and most commonly affect hoofstock
3. Infection is acquired when organisms contaminate a deep wound. In anaerobic environments, *Clostridia* release exotoxins, which cause injury to capillary endothelial cells and massive capillary leakage, leading to tissue swelling, which compromises blood flow, and favoring proliferation of disease. Death ensues rapidly
4. Signs include severe depression, regional swelling, and fever, but animals may just be found dead
5. Therapy can be successful if initiated early, but fatality is very high. Treatment includes prolonged antibiotic therapy, IV fluids, anti-inflammatory drugs, and drainage
6. Prevention is through good husbandry and hygiene. Multivalent vaccines are available

IX. *Chlamydia*
A. Epidemiology
1. Chlamydiosis has been found in birds, mammals, reptiles, and amphibians
2. *C. psittaci*, *C. abortus*, and *C. felis* can cause disease in humans
3. Elementary bodies are shed and are ingested or inhaled by a new host; then enter mucosal epithelial cells and form a cytoplasmic inclusion

B. Avian species: *Chlamydophila psittaci*
1. Infection has occurred in more than 150 species of birds
2. Spread by direct contact or by aerosol infection
3. Clinical signs may be mild to severe; signs include weight loss, anorexia, respiratory and GI signs with keratoconjunctivitis, rhinitis, dyspnea, and diarrhea. CNS signs are uncommon but can occur
4. Chlamydiosis should be a differential diagnosis in any sick bird, especially psittacines and columbiforms
5. Complement fixation is used for serology. PCR or culture can be used for diagnosis. For DNA-PCR testing, a choanal or cloacal swab is preferred. Liver, spleen, and air sacs are the preferred tissues for testing
6. If an infected bird is found, close public access until the situation can be assessed. Chlamydial infection is reportable in some states. Test other birds in the facility, and consider wild birds as a potential source of infection

C. Sheep, goats, cattle, and llamas: *Chlamydophila abortus*
1. Common cause of abortion in sheep and goats; occasionally affects cattle
2. Abortions are most common during the last 2 to 3 weeks of pregnancy
3. *C. abortus* has caused human abortions

D. Ruminants: *Chlamydophila pecorum*
1. Widely spread in ruminants
2. In sheep, keratoconjunctivitis and polyarthritis occurs; in goats, keratoconjunctivitis occurs

E. Domestic cats: *Chlamydophila felis*
1. Common source of acute and chronic conjunctivitis and upper respiratory infection
2. Most common in cats less than 1 year of age
3. *C. felis* has not occurred in zoo animals; it can occasionally occur in humans

F. Koalas
1. Infection is widespread in both wild and captive koalas. *C. pecorum* and *C. pneumoniae* have been isolated
2. Clinical signs include keratoconjunctivitis and infections of the urinary tract, reproductive tract, and respiratory tract
3. Transmitted by aerosols, direct contact, vectors, and ingestion of contaminated food
4. Tetracyclines are effective for treatment

G. Swine
1. Infection is widespread in pigs. *C. suis*, *C. pecorum*, and *C. abortus* have been isolated
2. Clinical signs may be inapparent but can include respiratory tract disease, generalized infection, conjunctivitis, polyarthritis, diarrhea, late abortion, and reproductive tract infection (in boars)
3. Tetracyclines are an effective treatment

X. *Yersinia*
A Definition
1. *Yersinia pseudotuberculosis* is the most important cause of clinical disease in captive wildlife and is particularly prevalent in Europe
2. *Yersinia enterocolitica* is increasing in frequency

B. Cause
1. Yersinia are small, aerobic, gram-negative coccobacilli
2. *Y. enterocolitica* and *Y. pseudotuberculosis* have similar pathological features. *Y. pseudotuberculosis* is a very important pathogen in captive species
3. *Y. pseudotuberculosis* is responsible for many cases of sudden death; the acute form is characterized by bloody, mucous diarrhea with death within 24 to 48 hours. Chronic forms cause debilitating illness with lesions in the liver, spleen, and kidneys.

C. Epidemiology
1. Reported in many species, including rodents, lagomorphs, marsupials, insectivores,

artiodactylids, perissodactylids, carnivores, primates, birds, reptiles, and fish
2. Many breeds serve as carriers, including wild birds, rodents, wild boar, deer, and domestic animals
3. New World primates, fruit bats, and some bird species are very vulnerable

D. Diagnosis
1. In acute cases, clinical signs include weakness, lethargy, heat-seeking behavior, progressing to depression and death within 24 to 48 hours
2. *Yersinia pseudotuberculosis* is easily isolated from liver and spleen
3. At necropsy, there is ulcerative, hemorrhagic enterocolitis in the small and large intestines, with multiple necrotic abscesses of the liver and spleen. Severe lymphadenitis with granulomatous lesions in mesenteric lymph nodes is seen in protracted cases
4. Differential diagnoses include infections caused by *E. coli* and *Salmonella*

E. Management and therapy
1. Wild birds and rodents have been considered carriers; however, this may not be the case. Houseflies are a probable vector. Cockroaches may also contribute to transmission
2. Vaccination of susceptible species is possible, but this can be problematic in large collections
3. Antibiotic use can prevent the spread to noninfected animals. *Yersinia* is susceptible to many antibiotics and does not develop resistance quickly
4. Stress is an important factor in development of disease. Controlling stress factors is important in prevention

XI. Fungal

A. Epidemiology
1. Histoplasmosis and cryptococcosis are associated with nitrogen-rich soils, which may be found in bat and bird roosts
2. Blastomycosis has a higher incidence in the Mississippi and Ohio River basins and Central Atlantic states
3. Histoplasmosis is more common in the valley and river terrains of the Midwest and Southern states
4. Coccidioidomycosis is more common in California

B. Transmission
1. Inhalation, trauma, and ingestion are the most common routes of transmission
2. Disease most commonly occurs in immunosuppressed or debilitated animals or in those that receive chronic antibiotic therapy

C. Pathogenesis
1. Fungi incite local and cellular immune responses
2. Fungi are phagocytosed by macrophages; activated macrophages cause tissue damage via the production of free radicals, inflammatory mediators, and hydrolytic enzymes
3. Hematogenous spread may occur

D. Diagnosis
1. Clinical signs relate to the organs infected
2. Immunodiagnostic tests are available for many fungal infections but might not always be reliable
3. Culture and sensitivity
 a. Sabouraud's dextrose agar is used, and incubation periods are longer than for bacteria
 b. Handling of cultures can pose a significant health risk
4. Gross pathology: Granulomas are the most common finding
5. Histopathology
 a. Most fungal infections are associated with granulomatous inflammation on sections
 b. A few fungal infections (such as blastomycosis and candidiasis) are more suppurative
 c. Fungal organisms may be identified in sections

E. Differential diagnosis
1. Other sources of granulomatous inflammation should be considered: TB, nocardiosis, actinomycosis
2. *Leishmania* infection can appear similar to histoplasmosis

F. Management and therapy
1. Ketoconazole: PO or topical; liver toxicity is an issue, and alanine aminotransferase should be monitored. Does not cross the blood-brain barrier
2. Enilconazole: Can be used as a spray for poultry enclosures. Also used for nasal infusion
3. Clotrimazole: Used topically, especially in otic preparations
4. Itraconazole: PO
5. Fluconazole: PO; use with caution in renal-impaired animals
6. Nystatin: Topical, or PO for GI diseases because it is poorly absorbed
7. Amphotericin B: Usually given IV; nephrotoxic, with many side effects
8. Flucytosine: PO administration is effective only against yeast. Crosses into the cerebrospinal fluid and can be used to treat cryptococcosis. Resistance develops quickly
9. Sodium or potassium iodide: Given PO
10. Griseofulvin: Effective for dermatophytes but not yeast. Oral absorption varies. Cheetahs may exhibit bone marrow suppression

G. Prevention
1. Vaccination is available for ringworm in cattle in Europe
2. Reducing stress and decreasing fungal levels in the environment is important

H. Causes
1. Aspergillosis: Most frequently in birds; air sacculitis and brooder pneumonia
2. *Blastomyces dermatitidis*: Pulmonary to systemic disease
3. Candidiasis: Skin disease in pinnipeds; frequently associated with immunosuppression causing disease at mucous membranes
4. *Fonsecaea* spp.: Skin nodules to systemic granulomatous infection, especially in amphibians
5. Chytridiomycosis: *Batrachochytrium dendrobatidis*. Cutaneous erosion to ulcers in amphibians

6. Coccidioidomycosis: Pulmonary infection with possible systemic spread
7. Cryptococcosis: Respiratory and CNS disease
8. Dermatophytosis: Ringworm caused by *Microsporum ectothrix*, *Trichophyton endothrix, Epidermophyton*
9. Histoplasmosis: Respiratory infection is most common
10. *Loboa loboi*: Granulomatous dermatitis
11. *Malassezia pachydermatis*: Mild dermatitis
12. *Nannizziopsis vriesii*: Dermatitis in reptiles
13. *Paracoccidioides brasiliensis*: Blastomycosis in South America
14. *Pneumocystis carinii*: Respiratory infection primarily in immunocompromised primates
15. Protothecosis: Algal disease; granulomatous dermatitis to systemic infection
16. Pythiosis: *Pythium insidiosum*
17. *Rhinosporidium seeberi*: Causes nasal polyps
18. Saprolegniasis: Proliferative dermatitis of aquatic species
19. *Sporothrix schenckii*: Lymphocutaneous granulomas; dissemination is rare
20. *Basidiobolus ranarum*: Erosive or ulcerative dermatitis in amphibians
21. *Conidiobolus coronatus*: Nasal polyps in mammals
22. *Fusarium* spp.: Dermatitis in pinnipeds
23. Mucoraceae: Low-grade granulomatous inflammation

XII. Rabies
- A. Cause
 1. Rabies is caused by several viruses in the *Lyssavirus* genus, not just the classic rabies virus (*Lyssavirus* serotype, genotype 1). Diseases produced by any *Lyssavirus* infection are indistinguishable
 2. *Lyssavirus* is of the Rhabdoviridae family and is a single-stranded RNA virus
- B. Epidemiology
 1. Lyssaviruses are distributed globally except for Antarctica
 2. Classic rabies is found in domestic dogs, carnivore reservoir hosts, and in most bat species
 3. About 0.1% of healthy bats in America or Europe are positive for *Lyssavirus* infection; up to 0.5% of Mexican bats may be infected
 4. Certain carnivores serve as a reservoir for rabies. In North America, the most common reservoir hosts are foxes, coyotes, raccoons, and striped and spotted skunks
 5. Domestic dogs are rabies reservoirs; rabies is endemic in free-ranging canid populations
 6. Rabies is shed in the saliva and is usually introduced by a bite wound. Less common routes are via scratches, aerosol, or mucous membrane exposure. The virus is transported centrally via peripheral nerves to spinal ganglia, then up the spinal cord to the brain. The virus then disseminates via nerve axons to the whole body. Virus is rarely found in urine, feces, reproductive or glandular fluids
 7. Incubation is variable, usually weeks to months, but can be months to years. Most animals develop clinical signs within 10 days. If clinical signs develop, the disease is fatal
 8. Clinical signs can go through several phases. During the furious phase, animals become aggressive and will bite anything. This will progress to paresis and flaccid paralysis, with death resulting from cardiac and respiratory failure. Other clinical signs include ataxia, seizures, behavioral changes, photophobia, hypersalivation, dysphagia, change in phonation, or mydriasis. Humans develop hydrophobia. Pharyngeal paralysis is common, which can be mistaken for an oral foreign body
- C. Diagnosis
 1. Rabies should be on the differential list for any neurologic disorder
 2. Histologically, Negri bodies (eosinophilic intracytoplasmic inclusions) may develop but are not always present. They usually occur in the hippocampal pyramidal cells or the cerebellar Purkinje's cells. Other than Negri bodies, the lesions look like any viral encephalitis
- D. Management
 1. Postexposure prophylaxis is recommended for persons exposed to rabies
 2. For captive nondomestic mammals exposed to a potentially rabid animal, the animal should be either euthanized or placed in a 6 month quarantine if not vaccinated. After 5 months, if there are no clinical signs of rabies, the animal should be vaccinated. If the animal was vaccinated prior to exposure, it should be revaccinated immediately, and observed for 90 days
- E. Prevention
 1. Preexposure vaccination is recommended for persons in frequent-risk occupations.
 2. Vaccination is recommended for domestic animals in areas where they may be exposed to rabies
 3. Prevent captive animals from being exposed to potentially rabid wildlife
 4. There are no parenteral rabies vaccines licensed for use in nondomestic species. Zoos are allowed to establish their own vaccination protocols for rabies. Nondomestic species do develop titers, but information regarding challenges with a virulent virus is limited
 5. Rabies prevention by oral vaccination in free-ranging reservoir hosts has been successful in some geographically defined areas in the United States and Europe. This has been used for control of rabies in raccoons, foxes, or coyotes. A recombinant vaccine is used, which cannot induce rabies as attenuated vaccines may

XIII. Pox diseases
- A. Orthopoxviruses
 1. Cowpox
 a. The origin of most mammalian pox disease in Europe and Asia. It affects many species, including squirrels, gerbils, voles, mice;

captive elephants, okapis, rhinoceros, anteaters, and most large cats
b. Transmissible to humans
c. Pathogenesis is unknown, but systemic spread following inhalation or ingestion of virus or infected prey has been suggested
d. In cats, there is severe generalized popular or ulcerated skin disease, with fatal pneumonia. Elephants show minor to severe skin ulceration, arthritis, foot lesions, conjunctivitis, or fatal systemic disease
e. Large eosinophilic intracytoplasmic inclusions similar to avipoxvirus are seen
f. Differential diagnoses include other poxviruses, calicivirus, bacterial or fungal dermatitis, and allergy. A skin biopsy is diagnostic
g. No specific treatment; antiviral agents may be effective but costly
h. Vaccines have been used in elephants in Asia but may not be effective. Rodent exposure should be controlled; any rodents used for feeding should be free of poxvirus

2. Monkeypox
a. The main poxvirus causing skin and systemic disease in nonhuman primates. Has also occurred in anteaters and humans; the reservoir may be squirrels
b. Consider monkeypox in any systemic febrile illness with a rash in primates. Pneumonia can occur, and mortality is high in orangutans
c. Differential diagnoses include herpesvirus, measles, or any causes of pneumonia
d. Vaccination with vaccinia is effective in primates and humans (but not widely available). However, with concerns of bioterrorism increasing, smallpox vaccines are once again being produced

3. Camelpox (Djidri)
a. Transmission is via direct contact or insect bites
b. Usually affects young camels at the time of weaning, and most cases are mild
c. A rash appears on the lips and may spread over the body. Secondary trauma from itching is common. No treatment is usually needed
d. Vaccines are available in Asia

4. Orthopoxviruses of cervids
a. Occurs in wild and captive mule deer and reindeer
b. Clinical signs are initially keratoconjunctivitis, followed by crusty face lesions. These lesions regress after a few weeks
c. Differentiate from contagious ecthyma (a parapoxvirus)

B. Parapoxvirus infections in mammals
1. Contagious ecthyma in ungulates (Orf)
a. Occurs commonly in sheep and goats; a similar disease occurs in wild ungulates
b. Transmission is via direct contact or by fomites. Scab material contamination of the environment is a problem. Immunity is short-lived, and reinfection can occur
c. Differential diagnoses include papillomatosis, orthopox, bacterial or fungal infection, and allergic response
d. Usually self-limiting, requiring no treatment
e. Cleaning of the environment is necessary. A camel virus vaccine has been developed in Asia

2. Parapoxvirus infection in red deer has occurred in New Zealand
3. Parapoxvirus infection in squirrels causes a severe, debilitating skin disease. Affects red squirrels; gray squirrels serve as a reservoir

C. Pox infections in marine mammals
1. Reported in the killer whale, harbor porpoise, many dolphin species, and pilot whale
2. Dolphinpox has considerable DNA similarity to terrestrial orthopoxviruses
3. Pinnipeds are affected by parapoxviruses and orthopoxviruses

D. Miscellaneous poxvirus infections of mammals
1. Primates: Yabapoxvirus and tanapox virus
2. Lagomorphs and squirrels: Leporipoxvirus; the most important is myxomatosis of rabbits
3. Lumpy skin disease of cattle is caused by a capripoxvirus (found in southern Africa)

E. Avipoxvirus infection in birds
1. Skin disease in featherless areas occurs in most cases; the mucous membranes of the mouth, respiratory tract, and eyes may also be affected (wet pox). Systemic disease may occur, especially in canaries
2. Most commonly seen in canaries, pigeons, galliformes, waterfowl, and diurnal raptors
3. Transmission is by direct contact, insect bites, fomites, or scab material
4. Lesions develop in 7 to 14 days
5. Clinical signs are typically proliferative dry lesions on featherless areas of the head and feet
6. Diagnosis is by histologic or electron microsopic examination of scrapings, impression smears, or biopsy. Eosinophilic inclusion bodies are seen in epithelial cells
7. Differential diagnoses include trauma, neoplasia, parasites, bacterial dermatitis, and papillomavirus
8. There is no specific treatment. Antibiotics, aspirin, and vitamin A therapy are recommended
9. Attenuated live vaccines are effective for specific species
10. Avipoxvirus is highly resistant in the environment but is killed by steam or 5% phenol

F. Poxvirus-like infections in reptiles, amphibians, and fishes
1. Affect mostly farm-raised crocodilian species
2. Transmission is probably direct contact or by arthropods
3. Lesions are on the skin and oral mucosa. In reptiles the skin lesions are brown or white flat patches or raised papules, which may ulcerate. Severe eye and mouth infections may cause death

XIV. Spongiform encephalopathy
- A. Introduction
 1. Spongiform encephalopathies are progressive, with long latent periods, and are fatal
 2. Spongiform encephalopathies infecting humans include kuru, Creutzfeldt-Jakob disease, fatal familial insomnia, and Gerstmann-Straussler-Scheinker disease
- B. Cause
 1. The cause is an alteration of a normal cellular protein called cellular prion protein
 2. The infectious prion is protease resistant, does not contain DNA or RNA, and has an abnormal protein configuration
- C. Pathogenesis
 1. The abnormal prion protein accumulates in the brain
 2. Typical histologic lesions are spongiform degeneration of the neuropil, neuronal vacuolization and degeneration, and astrocytosis
 3. In sheep with scrapie and deer with chronic wasting disease (CWD), the prion proteins appear first in lymphoid tissues and appear later in the brain
 4. Prions are very resistant to chemical disinfection. Prions are still infective after formalin fixation and autoclaving
- D. Scrapie
 1. First described in the 1730s; introduced into the United States in 1947
 2. Occurs in sheep and goats
 3. Transmitted after parturition, when infected fetal fluids pass into the environment
 4. Incubation is 3 to 5 years. Clinical signs include alopecia, nervousness, and ataxia
 5. There is a genetic predisposition; sheep are now being bred for natural resistance
- E. Transmissible encephalopathy of mink
 1. First observed in 1947 in ranch-raised mink
 2. May have resulted from the practice of feeding downer cattle to mink
 3. Natural outbreaks are rare
 4. Clinical signs include nervousness, debilitation, and ataxia
 5. Histologic lesions are in the brain and characterized by mild spongiform degeneration
 6. Immunohistochemical stains used to identify spongiform encephalopathies in ruminants do not stain mink
- F. Bovine spongiform encephalopathy (BSE)
 1. BSE was first diagnosed in 1986 in cattle in the United Kingdom and was subsequently diagnosed in bovidae in a zoo in England
 2. It has also been diagnosed in felids, including wild and domestic cats
 3. The source of infection of zoo animals was probably through the ingestion of meat and bone meal from sheep infected with scrapie
 4. Incubation period is 2 to 5 years
 5. Histologic lesions are characteristic of spongiform encephalopathies with spongiform degeneration of the neuropil and neuronal vacuolation and degeneration
- G. CWD
 1. Causes
 a. CWD is the only spongiform encephalopathy that occurs in wild and captive cervids
 b. First seen in captive deer in the late 1960s but not identified until 1979. First documented in a free-ranging elk in 1981. CWD has been documented in a number of states in captive herds. Unfortunately, not all states require postmortem testing for screening in captive deer and elk
 c. Naturally occurring CWD has only been documented in deer and elk, although other species can be experimentally infected. Hamsters and mice do not seem to be susceptible
 d. The zoonotic potential is unknown. Transmission is probably via ingestion of prions that contaminate food
 e. The incubation period is 2 to 5 years and may be longer
 2. Clinical signs
 a. Signs include weight loss to emaciation, excessive salivation, abnormal behavior (including loss of fear of humans), and mild ataxia
 b. Adipose tissue undergoes serous atrophy
 c. Histologic lesions are in the nervous system and are characterized by spongiform degeneration; vacuolar degeneration of neurons with neuronal loss; lymphoid depletion of tonsils, lymph nodes, and spleen
 3. Diagnosis
 a. Based on clinical signs and confirmed by the presence of abnormal prion protein in brain tissue and lymphoid tissue, with spongiform changes on examination of the brain
 b. Immunohistochemical stains are available to demonstrate prion proteins. This stain allows for early detection of infection in deer. This stain can also be used on tonsillar biopsies
 4. Treatment and prevention
 a. No known treatment
 b. No known screening tests, so prevention is difficult
 c. Evidence suggests that free-ranging deer may have been infected across fences by infected captive elk herds; thus the control of CWD in captive cervids is a top priority. Animals that die for any inapparent reason should have their brains examined for spongiform degeneration
 d. If an infected animal is found, the entire herd should be depopulated
 e. Prions in the environment are resistant to destruction

XV. Toxoplasmosis
- A. Introduction
 1. Caused by *Toxoplasma gondii*. More than 100 strains exist
 2. Belongs to the Sarcocystidae family

B. Epidemiology
 1. Infection is widespread; in the United States, about 58% of free-roaming cats, 37% of pet cats, and 22.5% of humans are seropositive
 2. There are three infective stages: shedding of sporozoites in cat feces, rapid reproduction of tachyzoites during active infection, and tissue cysts containing bradyzoites
 3. Transmission is via ingestion of sporulated oocysts from cats or of tissue cysts or tachyzoites from infected intermediate hosts. Infection can also occur transplacentally. Oocysts can contaminate water, grass, hay, or other feeds
C. Pathogenesis
 1. With ingestion of tissue cysts, bradyzoites are activated to become tachyzoites in the small intestine. Oocysts then form and are shed in the feces for 1 to 3 weeks. Ingested bradyzoites then penetrate through the intestine, multiply as tachyzoites, and spread to other tissues and become cysts
 2. Clinical signs are caused by tissue necrosis from tachyzoite multiplication
D. Clinical signs
 1. Most infected animals have no clinical signs, as the organism is distributed via lymphatics and blood vessels and forms tissue cysts. Once tissue cysts form, the infection is asymptomatic, except in immunocompromised individuals
 2. Infection during pregnancy can cause resorption, abortion, stillbirth, or congenital infection. In humans, infection during the first trimester is usually lethal to the fetus
 3. Rats, cattle, horses, and Old World monkeys are resistant to toxoplasmosis. New World monkeys and Australian marsupials are very sensitive to clinical disease
 4. In the wild, exposure is widespread
E. Diagnosis
 1. Serologic tests have been developed but may not work in zoo and wildlife species
 2. At necropsy, lesions can be found in many organs including lungs, lymphoid system, heart, skeletal muscle, liver, pancreas, eyes, intestines, and CNS. Pulmonary lesions are most common
 3. Tissue cysts containing bradyzoites are found usually in muscle and neural tissue and can occur within 1 to 2 weeks of infection. Bradyzoites are periodic acid-Schiff's positive
F. Treatment
 1. Elimination of the organism does not occur with treatment because no treatment kills the bradyzooites in tissue cysts
 2. Clindamycin is the treatment of choice for cats and dogs. A combination of two folic acid antagonists (pyrimethamine and sulfonamide) are used to treat humans, but a folic acid supplement should be administered
G. Prevention
 1. Vaccines are available for sheep and pigs. No vaccines have been effective for humans, cats, and nondomestic species
 2. Oocysts can remain infective for months to years
 3. Tissue cysts can be killed by freezing, heating to 67° C, or by soap and water, but no method is 100% effective
 4. Stray animals (especially cats) should be kept away from captive animals

XVI. Metabolic bone disease
A. Terms
 1. Rickets is the term used to describe inadequate mineralization of the matrix of growing bone, particularly at the growth plate or physis in long bones. It is typical of calcium or vitamin D deficiency in young animals
 2. Osteomalacia describes softening of bone, referring to loss of mineral from previously mineralized tissue
 3. *Osteopenia* refers to moderate loss of bone density, and *osteoporosis* refers to severe loss of bone density
 4. *Fibrous osteodystrophy* refers to the replacement of mineralized tissue by connective tissue, and is common in secondary hyperparathyroidism
 5. *Chondrodystrophy* refers to narrow growth plates with lack of matrix around chondrocytes. It is typically seen in manganese-deficient birds
B. Vitamins and minerals
 1. For a review of calcium metabolism and development of secondary hyperparathyroidism, refer to the review chapter on small animal endocrinology (Chapter 15, Endocrine Disorders)
 2. Vitamin D is necessary for proper calcium metabolism and bone growth
 3. Species that cannot synthesize vitamin D in the skin (felids and canids) or other species that are housed inside with no UV light exposure require adequate vitamin D in the diet. Some species, such as the Komodo dragon and green iguana, do not efficiently absorb vitamin D from the diet and must have exposure to UV light. Specific lights must be used as general lighting does not provide UV light
 4. Cow's milk, human milk, and other nonhuman primate milk is low in vitamin D, and UV light must be provided for nursing young
 5. Vitamin C, copper, and iron are required for proper collagen formation
 6. Vitamin A excess can cause spondylosis and tooth loss
 7. Manganese and zinc are also required for proper bone growth
 8. Excess fluoride is associated with impaired bone remodeling, mineralization of soft tissues, and hypermineralization of bone
C. Metabolic bone sisease of carnivores
 1. Rickets or osteomalacia is common in captive carnivores that have been fed predominantly skeletal muscle meat. Calcium concentration in muscle is low, with a Ca-to-P ratio of about 1:20

2. The low calcium intake allows hypocalcemia to develop, which in turn stimulates parathyroid hormone (PTH) production in an attempt to maintain serum ionized calcium concentration. The excess PTH upregulates calcitriol production, and both can activate osteoclasts, causing bone resorption
3. Canid and felid species are not able to synthesize vitamin D in the skin with UV light exposure; thus, proper amounts of calcium and vitamin D in the diet are critical
4. Komodo dragons do not absorb dietary vitamin D efficiently, and thus a UV light source is necessary

D. Metabolic bone disease of herbivores
1. Most herbivores eating plant leaves can meet their calcium requirements for maintenance and growth. Legume leaves are higher in calcium than are leaves of grasses
2. Phosphorus content of leaves tends to be lower than the calcium content but can be influenced by the soil content of phosphorus
3. Seed mixtures fed to psittacines are problematic because particular components can be picked out that are low in calcium and vitamin D (corn)
4. UV exposure is important for most primates, especially in the nursing young that are not consuming a balanced diet. Some primates, especially the colobus monkey, may produce milk with very low vitamin D concentration, as seen in cows and humans
5. The green iguana has limited ability to absorb vitamin D in the intestine; thus a UV light source is necessary

E. Metabolic bone disease of insectivores
1. Crickets, mealworms, and wax-moth larvae that are used for feeding are deficient in calcium. Purchased insects should have been fed a high-calcium food for a few days before feeding so that the gut contents are enriched with calcium
2. UV light exposure is important for most captive basking lizards in addition to calcium-fortified insects

Supplemental Reading

Fowler ME. *Restraint and Handling of Wild and Domestic Animals,* 3rd ed., 2008, Wiley-Blackwell.

Fowler ME, Miller RE. *Zoo and Wild Animal Medicine, Current Therapy,* 6th ed., St Louis, 2007, Saunders.

Dierauf LA, Gulland FMD, eds. *CRC Handbook of Marine and Mammal Medicine: Health, Disease, and Rehabilitation,* 2nd ed., 2001, CRC.

Index

A

AAFCO. *See* Association of American Feed Control Officials
Abamectin, 135
Abaxial sesamoid nerve block, 518, 518f
Abdominocentesis, 204, 502-503
Abiotrophies, 283
Abomasal displacement, 556-557, 556f, 557f
Abomasal emptying defect, 580
Abomasitis, 72, 580
Abomasopexy, 547
Abomasum, disorders of, 556-557, 580
Abortion, 82, 552-553, 576, 588
Abscesses
 cetaceans and, 656
 equine, 422
 facial, 35
 hepatic, 241
 hoof, 525
 liver, 563
 ovarian, 477
 prostatic, 343, 381
 rabbits and, 634
 reptiles and, 645
 retropharyngeal, 585
 rodents and, 638
 SC, 564
 sole, 550
 tooth, 573, 579
Acacia greffii, 140-141
Acanthocheilonema spp., 178, 178f, 179f, 361. *See also* Heartworm disease
Acanthocytes, 24, 25f
Accessory sex glands, 480-481, 481f
ACE inhibitors, 101-102, 187
Acer spp., 149
Acetabulum, 314
Acetaminophen toxicity, 146
Acetocholinesterase inhibitors, 132-133
N-Acetyl-β-D-glucosaminidase (NAG), 2
Acetylpromazine, 157
Acid-base balance, 4-6, 5t, 205
Acidosis, 5, 5f, 71, 220, 556, 580
Acne, 197
Aconitum spp., 115
Acorn poisoning, 120-121, 587
Acoustic enhancement, 53
Acoustic impedance, 53
Acoustic shadowing, 53
Acquired cardiac disease, 584
Acremonium lolii, 134
Acromegaly, 221-222
ACTH (adrenocorticotrophic hormone)
 response test, 210
 stimulation test, 430-431
Actinic dermatitis, 422
Actinobacillosis, 554, 579
Actinomycosis, 554, 554f, 579
Activated partial thromboplastin time (APPT), 255
Active immunization, 470
Acute atypical pulmonary emphysema and edema, 130, 565
Acute bovine pulmonary edema and emphysema, 560
Acute cystitis, 79
Acute gastritis, 229
Acute hepatic failure, 240-241
Acute lymphoblastic leukemia (ALL), 253, 299-300
Acute monocytic (M_5) leukemia, 254
Acute myeloblastic (M_1, M_2) leukemia, 253-254
Acute myeloid leukemia, 253-254
Acute myelomonocytic (M_4) leukemia, 254
Acute pain, defined, 163
Acute pancreatitis, 217-218
Acute primary (intrinsic) renal failure (AIRF), 386-388, 539
Acute respiratory distress, 561
Acute tubular nephrosis, 539-540
Addison disease, 79, 212-213, 213f, 216
Adenocarcinomas, 239, 304, 385, 477, 633
Adenomas, 79, 238, 429
S-Adenosylmethionine (SAM), 99-100
Adenoviruses, 74, 333t, 646
Adhesions, 506
Adrenal cortex, 210
Adrenal exhaustion syndrome, 432
Adrenal glands
 dermatoses and, 194
 diagnostic imaging of, 50
Adrenal glands *(Continued)*
 disorders of, 210-214, 213f, 432
 drugs for, 100-101
 necropsies and, 79
 neoplasias of, 626
 tumors of (equine), 463
 ultrasonographic imaging of, 55
Adrenal medulla, 79, 223
Adrenergic agonists, 96
β-2 Adrenergic agonists, 97
Adrenocortical adenomas, 79
Adriamycin, 171
Adulticide heartworm treatments, 340
Advantage, 337-338
Advantix, 338
Aeromonas spp., 648, 661-662
Aesculin, 138
Aesculus glabra toxicity, 138
Aflatoxins, 63, 124-125
African horse sickness (AHS), 445, 492
Afterload, defined, 165
Agglutination, 25, 25f
Aggression, horses and, 407
α-2 Agonists, 157, 401-402, 436
H_2 Agonists, 230, 230f
AHS. *See* African horse sickness
AI. *See* Aortic insufficiency
AIRF. *See* Acute primary (intrinsic) renal failure
Airway obstructions, 404-405
Alanine aminotransferase (ALT), 8-9, 13
Albumin, 12
Albuterol, 97
Aldosterone, 165
Aleutian disease, 626
Algae, 125-126, 133-134, 234
Alkali replacement, 202
Alkaline phosphatase (ALP), 8-9, 655
Alkaloids, 115-116, 127, 136, 139, 584-585
Alkalosis, 5, 5f
ALL. *See* Acute lymphoblastic leukemia
Allergic responses. *See also* Immune responses
 camelids and, 574-575
 emergency medicine and, 206
 fleas and, 194-195
 food and, 197, 420, 574-575
 rhinitis and, 355
 skin and, 196-197, 421, 423

Allium spp., 148-149
Alloantigens, 417
Allodynia, defined, 163
Allografts, 514
Allopurinol, 395f
Alopecia, 189, 194, 627, 630, 639, 640
Alopecic disorders, 423-424
ALP. *See* Alkaline phosphatase
Alpaca fever, 572
Alpacas, 570-576
ALT. *See* Alanine aminotransferase
Aluminum phosphide toxicity, 141
Alyssum, 152
Amaranthus spp., 121
Amaryllis spp., 145
Amebiasis, 645
Ameloblastoma, 307, 371
Amino acids, 290
Aminoglycosides, 103
Amiodarone, 96, 186
Amitraz, 109, 136, 192
Amitriptyline, 102
Amlodipine, 94, 187
Ammoniated forage toxicosis (bonkers), 565
Ammonium urate uroliths, 293, 393f, 394
Amnion, necropsies and, 82
Amphotericin B, 104
Amprolium toxicity, 589
Amputation, 320, 321-322
Amrinone, 97
Amsinckia intermedia, 63, 127
Amylase, 10
Amyloidosis, 76, 78, 244, 385
Anabaena spp. *See* Cyanobacteria
Anacystis aeruginosa, 125
Anagen defluxion, 424
Anal sac disease, 238
Anal sac mass, 377-378
Anal sac/apocrine gland adenocarcinoma, 304
Anal sacculitis, 376-377
Anal spasm, 238
Analgesia, defined, 163
Analgesics, 105-106, 163, 406. *See also* NSAIDs
Anaphylaxis, 206, 341, 561
Anaplasma spp., 26, 269
Anaplasmosis, 269, 562, 563f
Anconeal process, 324, 325f
Ancylostoma spp., 232-233
Androgens, 194
Anemia
 Babesia spp. and, 26
 classification of, 26-27
 equine, 414-417, 439
 ferrets and, 626
 hemolytic, 249, 256, 256f, 414
 overview of, 249-251, 250f
 viruses and, 250-251, 439
Anesthesia
 birds and, 615
 cetaceans and, 657
 equine, 401-406, 402t, 404t
 ferrets and, 625
 fish and, 648
 inhalation agents for, 159-161, 160t
 injectable agents for, 158-159
 machines and systems for, 155-156
 marine mammals and, 650
 myopathies after, 455
 nerve blocks and, 518, 518f
 pain and, 163-164
 patient monitoring and, 161-163
 pinnipeds and, 652
 preanesthetic agents and, 156-158
 rabbits and, 630
 reptiles and, 643-644
 ruminants and, 548-549
Anestrus, 350-352, 553
Angioedema, 423
Angiography, 165
Angiotensin, 165
Angiotensin-converting enzyme (ACE), 94, 386
Angular limb deformity (ALD), 52f, 468-469, 468f, 522, 576
Anion gap (AG), 5
Ankyloblepharon, 85
Anoplura, 419
Anorectal diseases, 236-239
Anorectal prolapse, 237
Anorexia, 644, 658
Antacids, 385
α-2 Antagonists, 402
Anterior cruciate ligament, 551
Anterior uvea, 88-89
Anthelminthic agents, overview of, 107
Anthrax, 445-446, 567-568, 660-661
Antiarrhythmics, 95-96, 186-187
Antibacterial drugs, 102-104
Antibiotics
 acute primary (intrinsic) renal failure and, 388
 antifungal, 104
 cetaceans and, 656
 chinchillas and, 639
 clostridial diseases and, 663
 fish and, 648
 hamsters and, 638
 primates and, 659
Anticholinergics, 157, 402-403
Anticoagulants, 106-107, 147-148, 417-418
Anticonvulsants, 107
Antidiarrheals, 98-99
Antiemetics, 98
Antifreeze toxicity, 6, 118-120, 282, 387-389
Antifungal drugs, 104
Antihistamines, 98, 180
Antiinflammatories, 99
Antiparasitic agent toxicity, 135
Aortic body tumors, 182
Aortic insufficiency (AI), 412-413
Aortic stenosis, 45, 166, 166f
Aortic thrombosis, 455
Aortic valves, 410-411
Aphanizomenon spp. *See* Cyanobacteria
Apnea, 405
Apocrine glands, 190, 239, 304
Apocynum spp., 114
Appendicular skeleton, 616
APTT. *See* Activated partial thromboplastin time
Arcanobacterium pyogenes, 66
Arginine, 292
Arginine vasotocin, 619
Arisaema triphyllum, 145
Armoracia spp., 149
Arrhenoblastomas, 477
Arrhythmias, 410, 559
Arrhythmogenic right ventricular cardiomyopathy, 173, 173f, 176
Arsenic toxicosis, 141-142
Arterial hypotension, 405
Arteriodilators, 187
Arteriovenous fistulas, 245
Arteritis, 445, 472, 482, 492
Arthritis
 caprine arthritis-encephalitis virus and, 586, 590-591
 of fetlock joint, 427
 immune-mediated, 329-331
 osteoarthritis (OA), 328-329, 519, 527, 530
 polyarthritis, 330, 637
 septic, 52f, 521-522, 551
Arthrogryposis, 553
Arthroplasty, 315
Artificial insemination, 351, 352, 482-483, 592
Aryepiglotic fold, 497
Arytenoid chondrosis, 498
Arytenoidectomy, 498, 499f
Ascarids. *See* Roundworms
Ascites, 239, 240
Asclepias spp., 114
ASD. *See* Atrial septal defect
Asebotoxins, 115
Aspartate aminotransferase (AST), 8, 13
Aspergillosis, 608, 622, 665
Aspergillus spp., 23, 63, 124
Aspirin poisoning, 107
Association of American Feed Control Officials (AAFCO), 291
AST. *See* Aspartate aminotransferase
Asteroid hyalosis, 91
Astragalus spp. toxicity, 137-138
Astroviruses, 267
Atenolol, 95, 186, 187t
Atherosclerosis, 69
Atlantoaxial joint instability, 307
Atlantooccipital space (AO), 448-449

Atony, uterine, 553
Atopy, 196-197, 420
Atresia, 238, 576
Atrial fibrillation, 185, 413
Atrial flutter, 185
Atrial septal defect (ASD), 165, 167
Atrioventricular block, 185
Atrioventricular valve dysplasia, 45, 169-170
Atrophic rhinitis, 595-596
Atropine, 139, 157
Attenuated vaccines, 470
Attenuation, 53
Atypical hyperadrenocorticism, 212
Atypical interstitial pneumonia, 561
Aujeszky disease, 267, 566
Aural plaques, 422
Auscultation, 410-411, 412f, 652-653
Autoantibody tests, 208
Autografts, 514
Avermectins, 109-110
Avian gastric yeast, 620
Avian influenza, 268, 604-605
Avian pox, 605, 667
Avian tuberculosis, 622-623
Avocado toxicity, 117
Avulsions, hoof wall, 525
Axial skeleton, 616
Azalea toxicity, 115
Azaperone, 157
Azathioprine, 99
Azodyl, 386
Azole antifungals, 104
Azotemia, 384, 539

B

Babesia spp., anemia and, 26
Babesiosis, 249, 250f, 562-563. *See also* Equine piroplasmosis
Babinski reflexes, 278
Bacillary hemoglobinuria, 663
Bacillus anthracis, 660. *See also* Anthrax
Bacillus cereus, 60
Backgrounding operations, 546
Bacterial endocarditis, 584
Bacterial infections
 abortion and, 82
 cytology of, 22
 diarrhea and, 234
 drugs for, 102-104
 ferrets and, 626
 fish and, 648-649
 food-borne infections and, 58
 open fractures and, 326-327
 osteomyelitis and, 327
 poultry and, 601-604
 primates and, 659
 reptiles and, 644
 rhinitis, sinusitis and, 354-355
Bacterial infections *(Continued)*
 rodents and, 636
 systemic infectious, 271-272
 urinary tract and, 390-391
 USDA and, 57
 uterine, 478
 wounds and, 368
Bacterial metritis, 347
Bacterial overgrowth, 236
Bacterial pneumonia, diagnostic imaging of, 44
Baermann technique, 11
Bain system, 156
Balanoposthitis, 345, 346
Balantidium, 233-234
BALP. *See* Bone origin
Bandages, birds and, 614-615, 614f
Bang's disease, 61, 554
Barbarea spp., 149
Barber pole worm, 72, 582
Barbiturates, 158
Bartonellosis, 271-272
Basal cell tumors, 303, 461
Base excess/deficit, 5
Basement membrane disorder, 385
Basophilia, 28, 252
Basophilic leukemia, 254
Basophilic stippling, 25
Basophils, 26
Bedding material, 544, 600
Bedlington terriers, 124
Beef industry, 545, 546. *See also* Ruminants
Behavior, 407-409, 623-624
Benazepril, 186t
Benign cutaneous histiocytoma, 21
Benign prostatic hypertrophy (BPH), 54, 343, 381
Benzodiazepines, 157, 402
Berserk male syndrome, 573
Bertoroa incana, 152
Bethanechol, 102
Big head disease, 218, 468
Bile acids, 9-10, 9f
Biliary tract, 239-246, 246f, 563
Bilirubin, 2-3, 9, 13, 112
Biopsies, 240, 342, 478-479
Biosecurity, 599
Biotin, 291, 646
Bird flu. *See* Avian influenza
Birds, 611-624, 660, 661, 664, 667. *See also* Poultry
Birnaviruses, 268, 605
Bisacodyl, 99
Bisphosphonates, 214
Biting, birds and, 624
Black disease, 663
Black flies, 607
Black walnut toxicity, 152
Blackhead, 607-608
Blackleg (*Clostridium chauvoei)*, 66, 656, 664
Bladder
 diagnostic imaging of, 48
 disorders of, 532-533
 neoplasias of, 380-381, 398-399
 rupture of, 541
 tumors of (equine), 463
 ultrasonographic imaging of, 54
Blastomas, 79, 307, 371, 477
Blastomycosis, 22, 273-274, 273f, 666
Bleeding time (BT) test, 255
Blepharitis, 85
Blindness, 465-466. *See also* Ophthalmology
Blister beetles, 143-144
Blister disease, 645
Bloat, 555-556, 555f, 579-580
β Blockers, 65, 95, 187, 187t
Blood
 anticoagulants and, 106-107
 birds and, 612, 613f
 cetaceans and, 655
 chemical evaluation of, 11-12
 fecal, 11
 ferrets and, 625-626
 glucose analysis and, 15
 rabbits and, 629
 rodents and, 636
 shock and, 205
 urinalysis and, 3
Blood gases, arterial sampling for, 203, 203f
Blood loss, 162, 249
Blood pressure, 161, 165, 205
Blood transfusions, 206
Blood urea nitrogen (BUN), 1, 655
Bloodworms, 472, 473t
Blubber, 655
Bluetongue virus (BTV), 579
Boating injuries, 651
Bobtailed disease, 150-151
Body condition scoring, 570, 578-579
Body temperature, 206. *See also* Thermoregulation
BoHV2. *See* Bovine herpesvirus 2
Bone cysts, 323-324
Bone marrow, 26-27, 28-30, 30f, 80
Bone origin alkaline phosphatase (BALP), 8
Bones, diseases of, 40, 322-324. *See also* Fractures
Bonkers, 565
Bordetella spp., 263-264, 333-334t, 336t, 659
Borrelia spp., 270, 334t
Borreliosis, 270-271
Bots, 473, 473t
Botulism, 59, 453, 566, 590, 609, 626
Bovine bonkers syndrome, 565
Bovine campylobacteriosis, 551-552
Bovine herpes mammilitis, 564
Bovine herpesvirus 2 (BoHV2), 564
Bovine leukemia virus (BLV), 562

Bovine respiratory disease (BRD) complex, 561-562
Bovine respiratory synyctial virus (BRSV), 561
Bovine spongiform encephalopathy (BSE), 63, 565, 668
Bovine trichomoniasis, 552
Bovine tuberculosis, 560-561
Bovine virus diarrhea virus (BVDV), 557, 561
Bovines. *See* Ruminants
Brachycephalic syndrome, 356, 382
Brachygnathia, 499
Bracken fern intoxication, 589
Bradyarrhythmias, 185
Bradycardia, 405
Brainstem, 82, 279-284
Bran disease, 218, 468
Brassica spp., 149
Braxy, 663
BRD complex. *See* Bovine respiratory disease complex
Breeder flocks, 600-601
Breeding, 575, 588, 592. *See also* Reproductive tracts
Brevetoxicoses, 651
Brightness mode (B-mode), 53
Broiler industry, 600-601
Bromethalein poisoning, 130, 282
Bromide, 107, 286
Bromocriptine, 431
Bronchiectasis, 358
Bronchitis, 264, 357-358, 358f, 560, 605
Bronchopneumonia, 359-360, 488
Bronchopulmonary diseases, overview of, 357-361, 358f
BRSD. *See* Bovine respiratory syncytial virus
Brucella spp., 61, 271
Brucellosis, 61, 554
Bruises, sole, 525
Brunsvigia rosea, 145
BT test. *See* Bleeding time test
BTV. *See* Bluetongue virus
Bubonic plague, 662
Bucked shins, 528-529
Bulking agents, 99
Bullas, defined, 189
Bullous disease, 198
Bumblefoot, 616. *See also* Pododermatitis
BUN. *See* Blood urea nitrogen
Bunyaviruses, 268
Bupivacaine, 406
Buprenorphine, 106, 158
Burns, 645
Burr cells, 25
Butorphanol, 97, 106, 158
Buttercups, 144
Butyrophenones, 157
BVD virus, 75

C

Cacatuidae, 611. *See also* Birds
CAEV. *See* Caprine arthritis-encephalitis virus
Caffeine, 130-131, 281
Cage paralysis, 639
Caiman pox, 647
CAIs. *See* Carbonic anhydrase inhibitors
Calcipotriol, 117
Calcitonin-secreting neoplasms, 79
Calcitrol, 117, 214, 386
Calcium
 bovine husbandry and, 543
 electrolyte metabolism and, 7-8
 fluid therapy and, 202
 hyperparathyroidism and, 468
 metabolic disorders of, 214-218, 215b, 215t, 217b, 217t, 669-670
 as nutrient, 290
 reptiles and, 646
 rickets and, 608
Calcium channel blockers, 96, 186, 187t
Calcium oxalate uroliths, 293, 380, 393f, 394
Calcium phosphate uroliths, 293, 393f, 394
Calf diphtheria, 560
Caliciviruses, 62, 263, 335t, 653
California encephalitis, 471
Calla spp., 145
Calli, defined, 190
Callitrichidae, 658
Caloric content, 292
Calves, scours and, 558-559
Camas toxicity, 116
Camelids, 570-576, 660
Camelpox, 667
Campylobacter spp., 58, 234
Campylobacteriosis (vibriosis), 551-552
Cancer eye, 567
Cancers, 295-296, 297. *See also* Neoplasias; *Specific forms*
Candida albicans, 23
Candidiasis, 608, 618
Canine acidophil cell hepatitis, 268
Canine chronic hepatitis, 242
Canine cyclic thrombocytopenia, 269
Canine herpesvirus (CHV), 268
Canine histoplasmosis, 75
Canine infectious tracheobronchitis, 264. *See also Bordetella* spp.
Canine parvovirus enteritis, 75
Canine teeth, 31, 37
Canine viral papillomatosis, 268
Canker, 608
Cannabis sativa toxicity, 139
Cannon bones, 427, 528
Cantharidin, 143-144
Caparsolate, 141-142
Capillaria hepatica, 638
Capnography, 162
Caprine arthritis-encephalitis virus (CAEV), 586, 590-591
Caprine management and husbandry, 577-591
Caps, 499
Capstar, 338
Carbamates, 109, 132-133, 282
Carbohydrates, 290
Carbonic anhydrase inhibitors (CAIs), 89
Carboxyatractyloside, 127
Carcinomas. *See also* Squamous cell carcinomas
 adenocarcinomas, 239, 304, 385, 477, 633
 anal sac/apocrine gland, 304
 follicular cell, 79
 ocular, 567
 perianal gland, 238-239
 renal, 385
 thoracic, pelvic, 321
 uterine, 633
Cardenolides, 114
Cardiac catheterization, 165
Cardiac valves, 410
Cardiomyopathies
 diagnostic imaging of, 45-46
 dilated, 45, 165, 171-174, 172f
 ferrets and, 627
 overview of, 171-176, 172f, 173f, 175f
Cardiopulmonary resuscitation (CPR), 205-206
Cardiovascular system
 acquired heart disease and, 171-185, 172f, 173f, 175f, 178f, 179t, 180f
 birds and, 619
 congenital heart disease and, 69-70, 166-171, 166f, 166t, 168f, 413
 congestive heart failure and, 165, 293-294, 627, 638
 CPR and, 205-206
 diagnostic tests for, 44-47, 165, 185
 disorders of in sheep and goats, 583-585
 drugs for, 95-97
 equine, 402t, 410-413
 ferrets and, 627
 medications for, 186-188, 186t, 187t
 necropsies and, 69-70
 physiology of, 165
 primates and, 659
 reptiles and, 642
 rodents and, 638, 640
 ruminants and, 559
Caries, 34
Carnassial teeth, 31
Carnitine, 291, 294
Carpal bone fractures, 428
Carpitis, 551
Carprofen, 406

Carpus, 311-312, 530
Cartilage, 328-329
Carvedilol, 186
Caseous lymphadenitis, 80
Castor beans, 144
Castration, 548
Casts, 3-4, 3f, 4f
Cat bags, 367
Cat scratch disease, 271-272
Catabolism, 290
Cataracts, 90, 90f, 637
Catarrhal rhinitis, 66
Catecholamines, 223
Caudal cervical spondylomyelopathy, 41, 307-308
Caudal cruciate ligaments, 317
Caudal heel pain, 426, 427, 526
Caval syndrome, 179, 181
Cavian leukemia, 641
CBC. *See* Complete blood counts
CC. *See* Creatinine clearance
C cell neoplasms. *See* Calcitonin-secreting neoplasms
CCP. *See* Critical control points
CDI. *See* Central diabetes insipidus
Cebidae, 658
Cecal dilation and volvulus, 558, 558f
Cecal worms, 607
Cecotrophs, 629
Cecum, 506-507, 506f, 629
Cellular casts, 3-4, 3f, 4f
Cellulitis, 84-85, 664. *See also* Strangles
Cementum, 31, 36, 499
Centaurea spp. toxicity, 137
Central core-like myopathy, 288
Central diabetes insipidus (CDI), 222
Central nervous system. *See* Nervous system
Cephalosporins, 102-103
Cercocarpus spp., 140-141
Cere, 617
Cerebellums, 279, 283, 553
Cerebrocortical necrosis, 589
Cerebrospinal fluid (CSF) analysis, 279, 448-449
Cerumens, 200
Ceruminous gland tumors, 303
Cervical lymphadenitis, 640
Cervical spondylopathy, 41, 307-308
Cervical static stenosis (CSS), 449
Cervical vertebral instability (CVI), 449
Cervical vertebral malformation (CVM), 449
Cervical vertebral stenosis (CVS), 449
Cervix, 475-476, 536-537
Cesarean sections, 348, 349f, 382, 547-548
Cestodes, 75, 571-572, 582, 649
Cetaceans, 654-657
CETP. *See* Cholesterol ester transfer protein
Chediak-Higashi syndrome, 251
Cheek teeth, 31, 37, 38, 500
Chelonians, 647
Chemical restraint, 366, 367, 494
Chemodectomas, 182
Chemotherapy, 297, 322
Cherry eye, 86, 86f
Chewing disease, 137
Cheyletiella spp., 195-196
Cheyletiellosis, 195-196
CHF, 363
Chickens. *See* Poultry
Chiggers, 195, 607
Chinchillas, 636, 639-640
Chives, 148-149
Chlamydia spp., 263-264, 335t, 622, 664
Chlamydiosis, 622
Chlamydophila, 618
Chlamydophilosis, 622
Chloride, 6, 290
Chlorinated hydrocarbon toxicity, 133
Choanal atresia, 576
Chocolate, 130-131, 281
Choke, 438, 438f, 555, 573
Cholangitis, 243
Cholecalciferol, 117
Cholecystitis, 77, 245
Cholelithiasis, 77, 246
Cholera, 61, 602
Cholestasis, 8-9
Cholesterol, 13
Cholesterol ester transfer protein (CETP), 14
Choline, 291
Chondrodystrophy, 669
Chondroids, 496
Chondrosarcomas, 302, 321
Chondrosis, 498
CHOP therapy, 299
Chorioallantois, 82
Chorioptic mange, 419, 419f
Chorioretinitis, 91-92
Chromium, 290
Chronic demodectic pododermatitis, 192
Chronic egg laying, 620
Chronic gastritis, 229-230
Chronic granulocytic (neutrophilic) leukemia, 254
Chronic kidney disease (CKD), 385-386
Chronic lymphocytic leukemia (CLL), 253, 300
Chronic myeloproliferative diseases, 254
Chronic obstructive pulmonary disease (COPD), 490-491, 491f
Chronic pain, defined, 163
Chronic proliferative synovitis, 527
Chronic renal failure (CRF), 384-385, 540
Chronic respiratory disease (CRD), 603
Chronic wasting disease (CWD), 668
Chronotropy, defined, 165
Chrysanthemum toxicity, 133
CHV. *See* Canine herpesvirus
Chylomicrons, 13-14
Chylothorax, 69, 363
CiALP. *See* Corticosteroid-induced alkaline phosphatase
Cicuta spp., 136-137
Cicutol, 136
Cicutoxin, 136
Ciguatera fish poisoning, 63
Circle anesthesia machines, 155
Circling disease, 59-60
Circoviruses, 596
Circulatory system, 146-150, 161
Cirrhosis, 77, 77f, 244, 294
Cisapride, 98, 99
Citrated blood, 12
CKD. *See* Chronic kidney disease
Claviceps spp., 151-152
Claws, removal of, 320
Cleft palate, 371
Clitoral hypertrophy, 349
CLL. *See* Chronic lymphocytic leukemia
Cloaca, 617-618, 620, 642, 645
Cloacal prolapse syndrome, 620
Clostridial diseases, overview of, 593-594, 663-664
Clostridial enteritis, 74
Clostridial myonecrosis, 551
Clostridial myositis, 66, 656, 664
Clostridium spp., 59, 234, 590, 663
Clotting, 106-107, 239, 240, 254-256, 255f, 417-418
Clover toxicity, 128, 140-141, 150, 153
CMO. *See* Cranial mandibular osteopathy
CO_2 absorption canisters, 156
Coagulation. *See* Clotting
Cobalamin, 253, 291
Cobalbumin, 251
Coccidioides immitis, 22-23
Coccidioidomycosis, 273, 273f, 665, 666
Coccidiosis
 bovines and, 565
 camelids and, 571
 necropsies and, 74
 overview of, 233
 poultry and, 607
 rabbits and, 632
 reptiles and, 647
 rodents and, 640
 sheep, goats and, 581-582
 swine and, 594
Cocklebur poisoning, 127
Codocytes, 25
Coelomic endoscopy, 614, 614f
Coital exanthema, 482
Colchicine, 100

Cold stress, 651. *See also* Thermo-regulation
Colibacillosis, 73, 593, 601-602, 662
Colic, 435-436
Colitis, 49, 75, 235, 295, 510-511
Collagenolytic granulomas, 423
Collateral ligaments, 317
Collie eye, 91
Colloid solutions, 202
Colobomas, 85, 92
Colocasia spp., 145
Colon. *See also* Intestine
 colitis and, 49, 75, 235, 295, 510-511
 large, 49, 231, 457, 507-511, 508f
 neoplasias of, 376
 small, 511-514
 transmissible murine colonic hyperplasia and, 637
Color-dilution alopecia, 194
Colostrum, 573
Comedones, 189
Complete blood counts (CBC), 24-26
Compound 1080 (sodium monofluoroacelate), 130
Compression radiography, 50
Concentric hypertrophy, 165
Condylar fractures, 528
Congenital arachnoid cysts, 282
Congenital conditions, camelids and, 576
Congenital dysplasia, 253
Congenital heart diseases (CHD), 69-70, 166-171, 166f, 166t, 168f, 413
Congenital myasthenia gravis, 288
Congenital ocular disease, 466
Congenital sensorineural deafness, 284
Congestive heart failure, 165, 293-294, 627, 638
Congestive splenomegaly, 258
Conium maculatum toxicity, 139-140
Conjugated (direct) bilirubin, 9
Conjunctiva, disorders of, 85-86, 465, 567
Connective tissue theory of laminitis, 468
Constipation, 99, 236-237, 237f, 645
Constrictive pericardial disease, 182
Contact dermatitis, 197, 421
Contagious ecthyma, 572, 579, 667
Contagious equine metritis, 482
Contrast procedures, 49
Convulsions, 107, 284-285
COPD. *See* Chronic obstructive pulmonary disease
Copper, 242-243, 290
Copper storage disease, 124
Copper toxicity, 76, 123-124, 294, 578, 583
Coprodeum, 617
Cor pulmonale, 559
Core vaccines, 332
Corn poisoning, 134
Cornea, 86-88, 87f, 465
Corneal reflexes, 93, 278
Coronaviruses, 74, 262, 266-267, 334t, 595, 605
Corticosteroid-induced alkaline phosphatase (CiALP), 8-9, 210
Corticosteroids, 180, 205
Coryza, 602
Cottonseed, 111-112, 544
Coumarin, 150
Coumestrol, 153
Cow calf industry, 545-546. *See also* Ruminants
Cowpox, 268, 666-667
COX inhibitors, 105
Coxofemoral joints, 315-316, 315f, 532
CPR. *See* Cardiopulmonary resuscitation
Crackles, 486
Cracks, hoof, 524-525
Cranial cruciate ligament, 317
Cranial mandibular osteopathy (CMO), 42
Cranial mesenteric artery, 73
Cranial nerves, 92, 277, 283-284, 447-448
Cranial pubic ligament, 369
Craniomandibular osteopathy, 35, 323
CRD. *See* Chronic respiratory disease
Creatine kinase (CK), 13, 112
Creatinine, 1
Creatinine clearance (CC), 1
Cricopharyngeal achalasia, 372
Critical control points (CCP), 57
Critical limits, 57
Crocodilians, 647
Crooked calf disease, 139
Crooked leg syndrome, 616
Crop stasis, 618
Crossties, 493
Cruciate ligaments, 317
Cruciferae toxicity, 149
Crustacean parasites, 649
Cryptococcosis, 274-275, 275f, 665, 666
Cryptococcus spp., 22
Cryptorchidism, 81, 344, 345, 381, 481, 534
Cryptosporidiosis, 62, 74
Cryptosporidium spp., 62, 580, 580f, 645
Crystalloid solutions, 201-202
Crystals, urinalysis and, 4
CSS. *See* Cervical static stenosis
Ctenocephalides felis, 195
Culicoides hypersensitivity, 419-420
Cushingoid-like syndrome, 429-431, 429f
Cushing's disease, 429-431, 429f
Cutaneous dermatophilosis, 653
Cutaneous habronemiasis, 422-423, 516
Cutaneous onchocerciasis, 421
Cutaneous papillomatosis, 423, 564
CVI. *See* Cervical vertebral instability
CVM. *See* Cervical vertebral malformation
CVS. *See* Cervical vertebral stenosis
CWD. *See* Chronic wasting disease
Cyanobacteria, 125-126, 133-134
Cyanogenic glycosides, 140-141
Cyanosis, 166
Cyclic flank alopecia, 194
Cyclohexamines, 158-159, 403
Cyclosporine, 99
Cynoglossum officinale, 63, 127
Cysteine, 292
Cystic calculi, 48
Cystic endometrial hyperplasia, 381
Cystic hyperplasia, 343
Cystic mucinous hyperplasia of the gallbladder, 77
Cystic ovarian disease, 54
Cystic ovaries, 553, 641
Cysticercosis, 62
Cysticercus fasciolaris, 637
Cystine uroliths, 293, 380, 393f, 395
Cystitis
 chole-, 77, 245
 diagnostic imaging of, 48
 equine, 541
 feline idiopathic, 391-392
 lympho-, 648
 necropsies and, 79
 rabbits and, 633-634
 rodents and, 641
Cysts
 bone, 323-324
 defined, 189
 epiglottic, 497
 feather, 616
 hepatic, 244, 637
 ovarian, 477
 uterine, 538
Cytauxzoonosis, 251
Cytology, 11, 18-23, 240

D

Dairy industry, 544-545. *See also* Ruminants
Dandruff, walking, 195-196
Datura stramonium toxicity, 139
dAVP. *See* Desmopressin
Dazzle reflex, 93
Deafness, 284
Deciduous teeth, 31, 36
Declawing, 320
Decoppering agents, 100
Defense spleen, 80
Degenerative joint disease, 51-52, 66
Dehorning, 548, 559-560
Dehydration, 4-5, 201-202
Delayed implantation, 652
Delayed union, 328
Delphinium spp. toxicity, 140

Delta receptors, 105
Democoidosis, 421, 639
Demodectic mange, 191, 191f, 193, 421, 422, 639
Dental caries, 34
Dental floats, 37
Dental resorptive lesions, 33
Dentin, 31, 36, 499
Dentistry
 anatomy and, 31-32, 32f, 35f, 36-37, 38f, 39f
 common diseases and, 32-35
 equine, 35-39, 35f, 38f, 39f
 lagomorphs and rodent, 35, 35f
Deoxynivalenol, 142
Department of Health and Human Services, 56
L-Deprenyl, 212
Dermatitis. *See also* Pododermatitis
 actinic, 422
 camelids and, 574
 contact, 197, 421
 digital, 550
 flea allergy, 194-195
 focal ventral midline, 420
 gangrenous, 603
 Malassezia, 196, 196f
 pastern, 422
 rabbits and, 630
 superficial necrolytic, 242
 udder cleft, 564
 vascular, 645
 zinc-responsive, 574
Dermatology. *See also* Skin
 autoimmune skin disorders and, 198-199
 birds and, 615-616
 endocrine, alopecic dermatoses and, 194
 equine, 419-424, 419f, 420f
 ferrets and, 627
 folliculitis and, 191-194, 191f, 192f
 immune-mediated disorders and, 199
 keratinization, metabolic skin disorders and, 197-198
 nodular skin disorders and, 199-200
 otitis and, 200
 patient assessment and, 189-190
 pruritic skin disorders and, 194-197, 195f, 196f, 419-420, 419f, 420f
 rabbits and, 630-631
 reptiles and, 645-646
 rodents and, 637, 638, 639, 640
Dermatomyositis, 199, 288
Dermatophilosis (rain rot/scald), 420, 420f, 564, 653
Dermatophilus congolensis, 22
Dermatophytosis (ringworm), 193, 421, 564, 574, 597
Dermis, overview of, 190-191
Dermoid inclusion cysts, 304
DES. *See* Diethylstilbestrol
Desflurane, 404t
Desmitis, 520
Desmopressin (dAVP), 222, 256
Desoxycorticosterone pivalate (DOCP), 101
Detomidine sedation, 494
Detrusor-urethral dyssynergia (DUD), 396-397
Dewclaws, 320
Deworming, 473-474, 473t
Dexamethasone, 101, 210, 232
Dexamethasone suppression test (DST), 210-211
Dextrose, 202
DI. *See* Diabetes insipidus
Diabetes, 222. *See also* Diabetes mellitus; Equine cushing-like syndrome
Diabetes insipidus (DI), 222
Diabetes mellitus (DM)
 birds and, 619
 cataracts and, 90
 diet and, 293
 drugs for, 101
 overview of, 218-220, 219b, 219f
 primates and, 657, 658, 659
Diacetocyscirpanol, 142
Diagnostic discordance, 16
Diaphragmatic hernias, 182, 363, 369-370
Diaphyses, 325-326
Diarrhea. *See also* Colibacillosis
 acute vs. chronic, 231, 232t
 bovine, 557-558, 561
 drugs for, 98-99
 overview of, 231-236, 232t
 primates and, 658
 rabbits and, 632
 reptiles and, 644-645
 rodents and, 637-639, 641
 sheep, goats and, 580, 581
Diastole, defined, 165
Diazepam, 157
DIC. *See* Disseminated intravascular coagulopathy
Dicentra spp. toxicity, 136
Dicoumarol toxicity, 150
Dieffenbachia spp., 145
Diestrus, 350-352, 381
Diet. *See also* Food safety; Nutrition
 diarrhea and, 232
 diseases and, 293-296
 equine, 472
 homemade, 292
 kidneys and, 385
 necropsies and, 71
 rabbits and, 629
Diethylcarbamizine, 181
Diethylstilbestrol (DES), 102
Diffuse parenchymal disease, 54
Difil test, 179, 181
Digestion, 11, 573-574
Digital dermatitis, 550
Digitalis glycosides, 187
Digitalis spp., 114
Digoxin, 96-97, 187, 187t, 412
Dihydropyridines, 187
Dilated cardiomyopathy, 45, 165, 171-173, 172f, 174
Diltiazem, 96, 186, 187t
Dinoflagellates, 63, 64, 651
Dipylidium spp., 233
Direct bilirubin, 9
Dirofilaria spp., 178, 178f, 179f, 361. *See also* Heartworm disease
Diseases of multiple species, overview of, 659-670
Diskospondylitis, 42
Dislocations, 305-306, 311-312
Displacement
 abomasal, 556-557, 556f, 557f
 equine GI disorders and, 436-437, 437f
 large colon, 508-510, 509f
Disseminated intravascular coagulopathy (DIC), 250, 256
Dissociative anesthetics, 403
Distemper, 172, 264-265, 333t, 627, 653, 656
Disulfiram-like toxins, 63
Diterpenoids, 115
Diuretics, 94, 101, 185-186
Diverticula, 228, 501-502
Diverting colostomy, 513
Diving, pinnipeds and, 652
Djidri, 667
DKA, 220
DM. *See* Diabetes mellitus
DNA vaccines, 470
Dobutamine, 96, 187
Dock toxicity, 120
DOCP. *See* Desoxycorticosterone pivalate
Dogbane, 114
Dolphin pseudopox, 653
Dopamine, 96, 101, 187
Dorsal metacarpal disease, 528-529
Dourine, 482
Dovonex, 117
Downer cow syndrome, 551
Doxorubicin, 299
Draschia megastoma, 72
Droperidol, 157
Dry coat, 433-434
DST. *See* Dexamethasone suppression test
Ductus deferens, 619
DUD. *See* Detrusor-urethral dyssynergia
Dugongs, 649-651
Duodenitis-proximal enteritis, 502
Dysentery, 74, 75, 594
Dysgerminomas, 477
Dysmaturity, 486-487

Dysplasias
atrioventricular valve, 45, 169-170
congenital, 253
elbow, 43, 324
hepatic microvascular (HMD), 245
hip, 43, 315-316
myelodysplastic syndrome, 253
renal, 385
retinal, 91
of TMJ, 306
tricuspid valve, 169-170
Dysplastic disorders, 253
Dystocia, 347, 553, 620, 639, 641, 645
Dystrophin-deficient muscular dystrophy, 287
Dysuria, 633-634

E

E. coli 0157:H7, 58-59
eACTH. *See* Endogenous adrenocorticotrophic hormone
Ear mites, 627, 630
Ears, 422
Eastern equine encephalitis (EEE), 442, 471
Ebola virus, 659
Eccentric hypertrophy, 165
Eccentrocytes, 25
Eccrine glands, 190
ECD. *See* Equine cushing-like syndrome
ECE. *See* Epizootic catarrhal enteritis
Echinocytes, 25
Echocardiography, 165
Echogenicity, 53
Echolocation, 655
Eclampuleravesia, 217
Ecthyma, 572, 579
Ectoparasiticides, 108-110
Ectopic testes, 81, 344, 345, 381, 481, 534
Ectopic ureters, 47, 78, 379-380, 396-397, 532, 541
Edema disease, 596
EDM. *See* Equine degenerative myeloencephalopathy
Edwardsiella spp., 649
EEE. *See* Eastern equine encephalitis
EEG. *See* Electroencephalography
Egg binding, 620
Egg-yolk peritonitis, 620
EGUS. *See* Equine gastric ulcer syndrome
Ehrlichia spp., 269
Ehrlichiosis, 269, 440
EHV-1. *See* Equine herpes virus I
EIA. *See* Equine infectious anemia
EIEC. *See* Enteroinvasive *E. coli*
Eimeria caviae, 640
Eimeria macusaniensis (*E. macusaniensis, E. mac*), 571
Elbows, 43, 312, 313f, 324, 530
Electrocardiography (ECG), 162, 165, 185
Electrocution, 544
Electroencephalography (EEG), 279, 449
Electrolytes, 1-2, 6-8, 201
Electromyelography (EMG), 449
Electrophoresis, 14
Elementary bodies, 622
Elephant skin, 190-191
Elizabethan collars, 365-366
Embryo transfer (ET), 483
Emergency medicine
anaphylaxis and, 206
blood transfusions and, 206
CPR and, 205-206
fluid therapy and, 201-203
heat stroke and, 206
shock and, 204-205
techniques for, 203-204, 203f, 204f
EMG. *See* Electromyelography
Emphysematous putrefactive disease, 649
Empyema, 67, 67f, 495-496
Enalapril-benazepril, 186t
Enamel, 31, 34, 36, 499
Encephalitis. *See also* Listeriosis
California, 471
caprine arthritis-encephalitis virus (CAEV) and, 586, 590-591
eastern equine (EEE), 442, 471
encephalitozoonosis, 634
meningo-, 280, 565, 657
necropsies and, 83
necrotizing, 280-281
primates and, 657
St. Louis, 471
thrombolytic, 565
vaccinations for, 471
western equine (WEE), 442, 471
Encephalitozoonosis, 634
Encephalopathies
bovine spongiform (BSE), 63, 565, 668
equine degenerative myelo- (EDM), 449, 451
equine leukoencephalomalacia, 134
feline ischemic, 281
feline spongiform, 268
granulomatous meningoencephalomyelitis (GME), 280
hepatic (HE), 100, 239, 240
mink transmissible, 668
polioencephalomalacia (PEM), 565, 573, 589-590
spongiform, 268, 668
transmissible spongiform (TSEs), 63
vascular, 281
End colostomy, 513
Endocardial cushion defects, 45
Endocardiosis, 176-177
Endocarditis, 70, 165, 177-178, 584
Endocardium, 69, 410
Endochondral cartilage, 324
Endocrine alopecia, 627
Endocrine system, 659
Endodontic disease, 33, 500
Endogenous adrenocorticotrophic hormone (eACTH), 210
Endometriosis, 477
Endometrium, 381, 478-479, 478f
Endomysium, 320
Endoparasite prevention, 107-108
Endotenon, 320
Energy requirements, 291, 292
Enflurane, 404t
Entamoeba, 233
Enteric redmouth, 649
Enteric septicemia, 649
Enteritis
camelids and, 574
canine parvovirus, 75
diagnostic imaging of, 49
diet and, 295
duodenitis-proximal, 502
gastro-, 235, 645
necrotic, 559, 603-604
overview of, 74
rabbits and, 632
rodents and, 640
ulcerative, 604
Enterohemorrhagic *E. coli*, 58-59
Enteroinvasive *E. coli* (EIEC), 59
Enterolithiasis, 511, 573-574
Enteropathies, 59, 235, 295, 594
Enteropathogenic *E. coli* (EPEC), 59
Enterosystemic cycle, 457
Enterotoxemia, 74, 559, 580, 581, 587, 632
Enterotoxigenic *E. coli* (ETEC), 59, 73, 580
Entrapment, 497, 503-504, 504f
Eosinopenia, 252
Eosinophilia, 28, 252
Eosinophilic gastritis and granuloma, 230
Eosinophilic gastroenteritis, 235
Eosinophilic leukemia, 254
Eosinophils, 19-20, 26
EPEC. *See* Enteropathogenic *E. coli*
Eperythrozoon coccoides, 637
EPI. *See* Exocrine pancreatic insufficiency
Epicauta spp., 143-144
Epidemiology, 492
Epidermal collarettes, 189
Epidermal glands, 190
Epidermal inclusion cysts, 304
Epidermis, 190, 597
Epididymis, 480
Epidural, 164, 548-549
Epiglottitis, disorders of, 496-497
Epilepsy, 284-285, 639
Epimysium, 320
Epinephrine, 97, 187
Epiphora, 639

Epiphyses, 325-326
Epiploic foramen entrapment, 503-504, 504f
Epistaxis, 496
Epitenon, 320
Epithelial cells, 3, 21, 303-304
Epizootic catarrhal enteritis (ECE), 56
EPM. *See* Equine protozoal myelitis
EPO. *See* Human recombinant erythropoietin
Eprinomectin, 135
Epulides, 371
Epulis, 306
Equine adenovirus, 445
Equine anhidrosis, 433-434
Equine bots, 72
Equine cushing-like syndrome (ECD), 429-431, 429f
Equine degenerative myeloencephalopathy (EDM), 449, 451
Equine gastric ulcer syndrome (EGUS), 436-438
Equine granulocytic ehrlichiosis, 440
Equine herpes virus (EHV), 443, 445, 488, 572
Equine hyperlipidemia, 14
Equine infectious anemia (EIA), 439
Equine influenza, 444-445, 471, 488
Equine leukoencephalomalacia, 134
Equine lower motor neuron (LMN) disease, 453
Equine metabolic syndrome, 431-432
Equine morbillivirus, 445
Equine motor neuron disease, 453-454
Equine piroplasmosis, 440
Equine protozoal myelitis (EPM), 440-442, 450-451, 450f
Equine recurrent uveitis, 465-466
Equine viral arteritis (EVA), 445, 472, 482, 492
Equisetum spp. toxicity, 140
Ergocalciferol, 117
Ergot toxicity, 151-152
Ericoline, 115
Erosions, defined, 190
Erosive arthritis, 329-330
Erysimum spp., 149
Erysipelas, 597
Erythema multiforme, 199
Erythrocytes, 26-27, 249-251, 250f, 655-656
Erythroid cells, 28-29
Erythroleukemia (M_6), 254
Erythromycin, 444
Erythropoietin, 102
Escherichia coli
 colibacillosis and, 73, 593, 601-602, 662
 enterotoxigenic (ETEC), 59, 73, 580
 overview of, 58-59, 662
Esmolol, 95, 186
Esophageal hypomotility, 226-227
Esophagitis, 227
Esophagoscopy, 227
Esophagus
 birds and, 617
 diagnostic imaging of, 48-49, 48f
 disorders of, 226-228, 228f, 372, 501-502
 megaesophagus and, 48-49, 48f, 71f, 226-227, 573, 579
 necropsies and, 70-71
Estrogens, 153, 194
Estrous cycle, 350-352, 479-480, 545, 553, 592. *See also* Pregnancy
ET. *See* Embryo transfer
ETEC. *See* Enterotoxigenic *E. coli*
Ether, 159
Ethylene glycol, 6, 118-120, 282, 387-389
Etomidate, 159
Euphorbia spp., 140-141, 144-145
Euthanasia, 546, 636
EVA. *See* Equine viral arteritis
Examinations, 611-612, 643
Excoriation, defined, 189
Exercise intolerance, 433-434
Exocrine pancreatic disorders, 246-247
Exocrine pancreatic insufficiency (EPI), 11, 247, 295
Exsanguination, 546
Extractions, dental, 500-501
Extrahepatic biliary obstruction, 246
Extravascular hemolysis, 414
Exuberant granulation tissue, 517
Exudative epidermitis, 597
Eyelids, 84, 85
Eyes. *See* Ophthalmology

F

Factor XII deficiency, 255
Failure of passive transfer (FPT), 573
Familial canine dermatomyositis, 288
Fanconi syndrome, 385
Far wall enhancement, 53
Farrowing, 592
Fat absorption tests, 11
Fats, stains for, 19
Fatty liver disease. *See* Hepatic lipidosis
FCoV. *See* Feline coronavirus
FCRD. *See* Feline central retinal degeneration
Fear, horses and, 409
Feathers, 615-616, 621-622, 624
Febantel, 107
Fecal fat, 11
Fecal flotation, 11
Fecal occult blood tests, 11
Fecal parasites, 11
Fecal starch, 11
Fecaliths, 238
Federal Food, Drug, and Cosmetic Act, 56
Feed additive toxicity, 112-113
Feedlots, 546
Feet. *See* Foot
Felicola subrostratus, 195
Feline acne, 197
Feline bartonellosis, 271-272
Feline bronchial disease, 358-359
Feline central retinal degeneration (FCRD), 91
Feline coronavirus (FCoV), 262
Feline dental resorptive lesions, 33
Feline dilated cardiomyopathy, 45-46
Feline foamy virus, 268
Feline gingivostomatosis, 33-34
Feline hepatic lipidosis. *See* Hepatic lipidosis
Feline hypertrophic cardiomyopathy, 45, 173-174, 175f
Feline idiopathic cystitis (FIC), 391-392
Feline immunodeficiency virus (FIV), 261-262, 336t
Feline infectious peritonitis (FIP), 75, 247, 250, 262-263, 335t, 363
Feline infectious respiratory disease, 263-264
Feline inflammatory liver disease, 243
Feline ischemic encephalopathy, 281
Feline kaliopenic nephropathy-polymyopathy syndrome, 6
Feline leukemia virus (FeLV), 250, 260-261
Feline panleukopenia virus (FPV), 75, 266, 334t
Feline plague, 272
Feline porphyria, 249
Feline poxvirus, 268
Feline progressive polyarthritis, 330
Feline spongiform encephalopathy, 268
FeLV. *See* Feline leukemia virus
Femoral head, avascular necrosis of, 43, 315
Femur fractures, 316, 532
Fenbendazole, 107
Fentanyl, 106
Feral horses, 407
Fermentation, 543
Ferns, 150
Ferrets, 625-628
Fescue toxicity, 151
Fetal death, diagnostic imaging of, 50
Fetlock joint, 427, 527
FHV-1. *See* Herpesvirus keratitis
Fiber, 235, 290, 457-458
Fibrin, 255
Fibrinogen, 12
Fibroblasts, 320, 515
Fibropapillomas (warts), 656. *See also* Papillomatosis
Fibrosarcomas, 300, 302, 304, 307, 321, 371
Fibrosis, 244, 254, 385

Fibrotic myopathy, 521
Fibrous osteodystrophy, 66, 669
Fibular fractures, 318
FIC. *See* Feline idiopathic cystitis
Fighting teeth, 571
Figure eight bandages, 614-615, 614f
Filaribits, 336, 337t
Filtration, fish and, 648
Final Rule on Pathogen Reduction, 56
FIP. *See* Feline infectious peritonitis
Fipronil, 109
Fireweed, 127-128
Fish, 648-649, 660
Fish oil, 294
Fish toxins, 63
Fissures, defined, 190
Fistulas, 225, 228, 238, 245
Flaviviruses, 268, 623. *See also* West Nile virus
Flea allergy dermatitis, 194-195
Flea control, 107-108, 133, 336-338, 337t
Fleas, rodents and, 640
Flecainide, 186
Flexural limb deformities, 522-523
Flippers, 651
Flooring, 544
Fludrocortisone, 101
Fluid status, 4-6, 94
Fluid therapy, 201-203
Flukes, 241, 270, 563, 572, 582
Flunixin, 406
Fluorescein dye, 84, 465
Fluoroquinolones, 103
Fluprostenol, 480
Flutter valves, 156
FMCP. *See* Fragmented medial coronoid process
FMD. *See* Foot-and-mouth disease
Foals
 behavioral development of, 408
 birth of, 483-484, 484f
 gastrointestinal diseases of, 435
 meconium impaction and, 512
 newborn, 484
 respiratory function and, 486-487, 487f
 restraint of, 493-494
 vaccination of, 470-471
Foamy virus, 268
Focal myasthenia gravis, 289
Focal ventral midline dermatitis, 420
Fog fever, 123, 560
Folic acid, 11, 253, 291
Follicles, 190
Follicular casts, 189
Follicular cell carcinoma, 79
Folliculitis, 191-194, 191f, 192f, 420-421
Food allergies, 197, 420, 574-575
Food and Drug Administration, 56
Food safety, 56-64
Food Safety and Inspection Service (FSIS), 56
Food-borne disease outbreaks (FBDO), 57
Foot, 425, 426f, 524-530, 550, 568, 579
Foot warts, 550
Foot-and-mouth disease (FMD), 568, 579
Footrot, 550
Forage, 453, 472, 577
Forebrain lesions, 279-280
Foreign animal disease, 446
Foreign bodies
 anorectal, 238
 cetaceans and, 657
 esophageal, 227, 372
 ferrets and, 56
 gastric, 229, 373-374
 intestinal, 374-375
 penis and, 346
 pinnipeds and, 654
 rhinitis, sinusitis and, 355
 rodents and, 641
Forestomachs, 71, 555-556, 555f
Foul in the foot, 550
Fowl cholera, 602
Fowl typhoid, 602-603
Foxglove toxicity, 114
FPT. *See* Failure of passive transfer
FPV. *See* Feline panleukopenia virus
Fractures
 birds and, 616
 of carpus, 312-314
 diagnostic imaging of, 40
 of distal extremities, 319-320
 equine, 518-519, 522-532
 of femur, 316
 of foot, 425-427
 of humerus, 310-311
 improper healing of, 328
 mandibular, 305-306
 maxillary, 306
 olecranon, 311
 open, 326-327
 pediatric, 325-326, 326f
 pelvic, 314
 rabbits and, 634
 of radius and ulna, 311-312
 of scapula, 309-310
 of shoulder, 309-310
 skull, 305
 spinal, 308-309
 of third phalanx, 525-526
 of tibia and fibula, 318
 of trochlear notch, 311
Fragmented medial coronoid process (FMCP), 324-325
Francisella tularensis, 272
Free T_3 test, 208
Free T_4 test, 208
Frontal sinuses, 305
Frontline Plus, 337
Frontline Top Spot, 336-337
Frothy bloat, 580
Fructosamine, 15
FSIS. *See* Food Safety and Inspection Service
Fumonisins, 134
Fundus, diseases of, 91-92
Fungal infections. *See* Mycoses
Fur chewing, 639
Furosemide, 94, 186, 186t, 214, 412
Furunculosis, 420-421, 648
Fusarium spp., 134, 142, 152-153
Fusobacterium necrophorum, 550

G

Gag reflex, 278
Gait, neurologic evaluation and, 277
Gallbladder
 cystic mucinous hyperplasia of, 77
 diagnostic imaging of, 47
 mucocele of, 245-246
 necropsies and, 76
 rats and, 638
 ultrasonographic imaging of, 53
Gamma-glutamyltransferase (GGT), 2, 9
Gammopathies, 12
Gangrene, 549, 603, 645, 664
Garlic, 148-149
Gastric acid secretion, 230, 230f
Gastric dilation (GD), 49, 72
Gastric dilation-volvulus (GDV), 49, 49f, 231, 295, 373f
Gastric motility disorders, 230
Gastric outflow obstruction, 230
Gastric ulcer disease, 654
Gastric yeast, 620
Gastrinomas, 222-223
Gastritis, 56, 229-230, 294-295
Gastroduodenal ulceration and bleeding, 229
Gastroenteritis, 235, 645
Gastroesophageal intussusception, 228
Gastrograms, 50
Gastrointestinal dysfunction. *See* Colic
Gastrointestinal tract
 birds and, 617-618
 cetaceans and, 655
 clostridial diseases of, 663
 disorders of (equine), 435-438, 437f, 438f
 disorders of in sheep and goats, 579-580
 disorders of in swine, 593-595
 ferrets and, 627-628
 rabbits and, 632-633
 reptiles and, 642, 644-645
 ruminants and, 554-559
 surgery and, 371-379, 375f, 377f, 378f, 499-514
 toxicology and, 141-146
 tumors of (equine), 463

Gastropathy, hypertrophic, 231
Gauze muzzles, 365, 366f
GD. *See* Gastric dilation
GDV. *See* Gastric dilation-volvulus
Generalized idiopathic tremors, 281
Generalized myasthenia gravis, 288
Genitalia, tumors of (equine), 463
Gerbils, 636, 639, 639f
GFR. *See* Glomerular filtration rate
GGT. *See* Gamma-glutamyltransferase
Giardia, 233, 334t, 336t, 637
Gingival sulcus, 31
Gingivitis, 32, 225
Gingivostomatitis, 33-34
Gizzards, 599
GKX, 405
Glanders, 446
Glandular stomachs, 600
Glargine, 101
Glasser disease, 596
Glaucoma, 89-90
GLDH. *See* Glutamate dehydrogenase
Glipizide, 101
Globoid cell leukodystrophy, 287
Globulin, 12
Glomerular filtration rate, 1
Glomerulonephritis, 77-78, 385, 637
Glomerulopathy, 385
Glucocorticoid hepatopathy, 10, 76
Glucocorticoids, 97-98, 99, 104-105, 206, 214, 242
Glucosamines, 329
Glucose, 2, 14-16, 112, 218-221, 219b, 219f
Glucose curves, 219f
Glucose tolerance test (GTT), 15, 431
Glucosinolates, 149
Glucosuria, 385
Glutamate dehydrogenase (GLDH), 8
Glutaraldehyde coagulation test, 12
Gluticasone, 97-98
Glycated hemoglobin, 15
Glycogen storage disease, 287, 288
Glycopyrrolate, 157
Glycosaminoglycans, 328, 329
GME. *See* Granulomatous meningoencephalomyelitis
Goat pox, 579
Goats. *See* Caprine management and husbandry
Goiter, 432, 433f, 619
Gold dust disease, 649
Gonadal dysgenesis, 476
Gonadotropin-releasing hormone (GnRH), 479
GOSHDARNIT mnemonic, 215b
Gossypol toxicity, 111-112, 544
Gout, 618-619, 646
Grain overload, 71, 556
Grains, 458
Gram staining, 18
Gram-negative bacteremia with pneumonia, 487-488
Granular casts, 3, 4f
Granulocytes, 29
Granulocytic ehrlichiosis, 440
Granulomatous inflammation, 20
Granulomatous meningoencephalomyelitis (GME), 280
Granulomatous pulmonary diseases, 360
Granulomatous urethritis, 399-400
Grapes, 117, 388
Grass tetany, 7, 551
Grayanotoxins, 63, 115
Grease heel, 422
Great apes, 658-659
Grecian foxglove, 114
Griseofulvin, 104
Growth hormone (GH), 221-222
GTT. *See* Glucose tolerance test
Guaifenesin, 159, 403, 405
Guanacos, 570-576
Guillain-Barré syndrome, 452
Guinea pig paralysis, 641
Guinea pigs, 58, 636, 640-641, 640f
Gumboro, 605-606
Guttural pouch, 461-462, 495-496
Guttural pouch empyema, 67, 67f, 495-496

H

Habronemiasis, 422-423, 516, 536
HAC. *See* Hyperadrenocorticism
HACCP System. *See* Hazard Analysis and Critical Control Point System
Haemonchus contortus, 72, 582
Hageman's factor, 655
Hair, 190, 191-194, 191f, 192f, 296. *See also* Dermatology
Hair rings, 640
Hairballs, 294, 633
Hairy heel warts, 550
Halogeton glomeratus, 120
Halothane, 160t, 404, 404t
Hamsters, 636, 638-639
Hand breeding, 482
Hantavirus, 268
Hardware disease, 71, 556
Hatchlings, 623
HAV. *See* Hepatitis A virus
Hazard Analysis and Critical Control Point (HACCP) System, 56-57
HDL. *See* High-density lipoproteins
HE. *See* Hepatic encephalopathy
Head tilt, 637, 641
Heart failure, 165
Heart rates, 161
Heart sounds, 411
Heartguard, 336, 337t, 340. *See also* Ivermectin
Hearts, 69, 111-117, 642. *See also* Cardiovascular systems
Heartworm antigen test, 179, 181
Heartworm disease
 anemia and, 250
 canine vs. feline, 339t
 diagnostic imaging of, 45, 45f
 ferrets and, 627
 overview of, 178-182, 178f, 179t, 180f, 338-341, 339t
 pathophysiology of, 339-340
 pinnipeds and, 653
 preventatives for, 107-108, 332, 336, 337t
 treatment of, 340-341
Heat stroke, 206
Heifer facilities, 547
Heinz bodies, 25
Heinz body anemia, 27, 250, 250f, 414-416
Heliotropium curassavicum, 63, 127
Helminths, 232-233
Hemangiomas, 461
Hemangiopericytomas, 300
Hemangiosarcomas, 183, 301, 302, 304, 321
Hematology, 24-30, 414-418, 562-563
Hematomas, 476, 476f
Hematopoietic system, 80
Hematuria, 3, 633-634
Hemerocallis spp., 121, 388
Hemihopping, 277
Hemipene prolapse, 645
Hemiplegias, 497
Hemobartonella muris, 638
Hemochromatosis, 657, 658
Hemodynamic theory, 467-468
Hemoglobin, 24
Hemoglobinuria, 663
Hemolymphatic tumors (equine), 462-463
Hemolysis, 414
Hemolytic anemias, 249, 256, 256f, 414
Hemomelasma ilei, 73
Hemophilia, 255
Hemoplasmosis, 26, 249
Hemorrhages, 20-21, 58-59, 82, 92, 405, 538
Hemorrhagic bowel syndrome, 558
Hemorrhagic enteritis, 74
Hemorrhagic syndrome, 558, 641
Hemothorax, 69, 363
Hemps, 114
Henderson-Hasselbach equation, 5
Heparin, 106-107, 255, 256
Hepatic amyloidosis, 244
Hepatic cysts, 244, 637
Hepatic diseases. *See* Liver
Hepatic encephalopathy (HE), 100, 239, 240
Hepatic failure, 240-241
Hepatic lipidosis, 10, 76, 241, 294, 563, 574, 618

Hepatic microvascular dysplasia (HMD), 245
Hepatitis, 61-62, 242-244, 267-268, 294, 618, 659
Hepatitis A virus (HAV), 61
Hepatitis E virus (HEV), 61-62
Hepatocutaneous syndrome, 198, 242
Hepatocytes, 8
Hepatozoonosis, 276
Herbicides, 122, 141-143
Hermaphroditism, 381, 481
Hernias
 diagnostic imaging of, 47
 diaphragmatic, 182, 363, 369-370
 hiatal, 228, 372
 inguinal, 505, 534, 534f, 658
 perineal, 237-238
 surgery and, 369-370
Herpes myelitis, 452
Herpesvirus keratitis (FHV-1), 87
Herpesviruses
 birds and, 621
 bovine, 564
 canine, 267, 268
 cetaceans and, 656
 equine, 443, 445, 488, 572
 feline, 87
 myelitis and, 452
 pinnipeds and, 653
 primates and, 657, 658
 reptiles and, 647
Hetastarch, 202
Heteromeles arbutifolia, 140-141
HEV. *See* Hepatitis E virus
Hiatal disorders, 228
Hiatal hernias, 228, 372
High 4 point nerve block, 518, 518f
High-altitude disease, 137-138
High-density lipoproteins. (HDL), 13-14
Hip dysplasia, 43, 315-316
Hip luxation, 550-551
Hip replacement, 316
Hirsutism, 429, 429f
Histamine poisoning, 64, 654
Histamine type 2 (H_2) blockers, 98
Histiocytic inflammation, 20
Histiocytic ulcerative colitis, 235
Histiocytomas, 304
Histology, cytology vs., 18-19
Histomoniasis, 607-608
Histophilus somnus, 561-562
Histoplasmosis, 22, 75, 272-273, 273f, 665
HMD. *See* Hepatic microvascular dysplasia
HO. *See* Hypertrophic osteopathy
Hock, 428
HOCM. *See* Hypertrophic obstructive cardiomyopathy
HOD. *See* Hypertrophic osteodystrophy
Holly, 145-146
Holter monitoring, 165
Homemade diets, 292
Honey intoxication, 63
Hookworms, 75, 232-233, 653
Hooves, 524-530, 550
Hormone-responsive incontinence, 396
Horner syndrome, 93, 93f, 448, 466
Horse chestnuts, 138
Horsetail, 140
Housing
 birds and, 611
 marine mammals and, 650
 pinnipeds and, 652
 poultry and, 600
 primates and, 658
 rabbits and, 629
 reptiles and, 643
 rodents and, 636
Howell-Jolly bodies, 25
HTLV-1. *See* Human T-lymphotrophic virus
Huacya llamas, 570
Human chorionic gonadotropin (HCG), 479
Human recombinant erythropoietin (EPO), 102
Human T-lymphotrophic virus (HTLV-1), 659
Humerus, fractures of, 310-311, 530-531
Humoral hypercalcemia, 216
Hyacinthus spp., 145
Hyaline casts, 3
Hydralazine, 94-95, 187
Hydranencephaly, 82
Hydrangea spp., 140-141
Hydrocephalus, 82, 282
Hydrochlorothiazide, 186, 186t
Hydrocodone, 97
Hydromorphone, 106, 158
Hydronephrosis, 47
Hydrothorax, 68-69
Hymen, persistent, 349
Hyoscyamine, 139
Hyovertebrotomy, 496
Hyperadrenocorticism (HAC), 50, 194, 210-212. *See also* Equine cushing-like syndrome
Hyperaldosteronism, 213-214
Hyperandrogenism, 194
Hyperbilirubinemia, 13
Hypercalcemia, 8, 214-216, 215b, 215t, 389
Hypercholesterolemia, 13
Hyperchylomicronemia, 14
Hyperesthesia, defined, 163
Hyperestrogenism, 194
Hyperextension, 523
Hyperfibrinogenemia, 12
Hyperflexion, 523
Hyperglycemia, 15, 219b
Hypericum perforatum, 152
Hyperkalemia, 6-7, 405, 454
Hyperkeratosis, 190
Hyperlipidemia, 14
Hypermagnesemia, 7
Hypernatremia, 6, 589
Hyperostosis, 616
Hyperparathyroidism, 8, 218, 433, 468, 646
Hyperpathia, 285-286
Hyperphosphatemia, 7
Hyperpigmentation, 189
Hyperplasias
 cystic, 343
 cystic endometrial, 381
 cytology and, 21-22
 hepatic nodular, 244
 nodular, 258
 rabbits and, 633
 vaginal, 350
Hypersensitivity reactions, 195, 196. *See also* Anaphylaxis
Hypersplenism, 258
Hypertension, 183-184, 386
Hyperthermia, 572-573, 639, 654
Hyperthyroid cardiomyopathy, 45-46
Hyperthyroidism, 79, 209-210
Hypertonic dehydration, 5, 201
Hypertonicity syndrome, 288
Hypertriglyceridemia, 13
Hypertrophic cardiomyopathy, 45, 173-174, 175f
Hypertrophic gastropathy, 231
Hypertrophic obstructive cardiomyopathy (HOCM), 173-174
Hypertrophic osteodystrophy (HOD), 41, 42f, 322-323
Hypertrophic osteopathy (HO), 323
Hypertrophies
 benign prostatic (BPH), 54, 343, 381
 clitoral, 349
 concentric, eccentric, 165
 feline hypertrophic cardiomyopathy, 45, 173-174, 175f
 ileal, 505-506
Hypervitaminosis D, 646
Hypoadrenocorticism, 79, 212-213, 213f, 216
Hypoalbuminemia, 12
Hypobiosis, 582
Hypocalcemia, 7-8, 216-218, 217b, 217t, 551, 578
Hypocalcemic tetany, 455
Hypoderma, 564
Hypoglobulinemia, 12
Hypoglycemia, 14, 220-221, 647, 658
Hypokalemia, 6
Hypolipidemia, 14
Hypomagnesemia, 7
Hyponatremia, 6, 654
Hypophosphatemia, 7, 27
Hypopigmentation, 189

Hypoplasias
cerebellar, 283, 553
enamel and, 34
epiglottic, 496-497
ovarian, 476
penile, 346
primary portal vein (PPVH), 245
pulmonary with anasarca (PHA), 553
vulvar, 348-349
Hypospadia, 346
Hyposplenism, 258
Hypothalamus, 208, 429
Hypothyroidism, 194, 208-209, 282, 432-433, 619
Hypotonic dehydration, 5
Hypotrichosis, 553
Hypovitaminosis A, 608-609
Hysterectomy, 348

I

IBD. *See* Irritable bowel disease
iCa. *See* Ionized calcium
ICH. *See* Infectious canine hepatitis
Ich (*Ichthyophthirius multifiliis)*, 649
IDDM. *See* Insulin-dependent diabetes mellitus
Idiopathic facial paralysis, 283
Idiopathic hepatic lipidosis, 241-242
Idiopathic hypercalcemia, 8
Idiopathic hyperlipidemia, 14
Idiopathic incontinence, 396
Idiopathic inflammatory brain disorders, 280
Idiopathic myelofibrosis, 254
Idiopathic prostatitis, 343
Idiopathic thrombocytopenic purpura (ITP), 417-418
Idiopathic vestibular disease, 283
IDL (intermediate density lipoproteins), 13-14
IGF-1. *See* Insulin-like growth factor
Ilex spp., 145-146
Ilium, 314, 505-506
Imaging. *See also* Ultrasonography
abdominal (small animal), 47-50, 48f, 49f
orthopedic (large animal), 31-52, 51f, 52f
orthopedic (small animal), 40-43, 41f, 42f
overview of, 40
thoracic (small animal), 43-47, 45f, 46f
IMHA. *See* Immune-mediated hemolytic anemia
Imidacloprid, 109
Immiticide, 141-142, 180, 340
Immune system, 198-199, 256-257, 256f, 329-331, 421. *See also* Allergic responses
Immune-mediated anemia, 256, 256f, 416
Immune-mediated hemolytic anemia (IMHA), 256, 256f
Immune-mediated orchiditis, 344
Immune-mediated thrombocytopenia (IMT), 257
Immunoglobulins, 12
Impactions
abomasal, 557
ascarid, 502
cecal, 506-507
ileal, 505-506
large colon, 508
meconium, 512
small colon, 511-512
Imprinting, 573, 624
IMT. *See* Immune-mediated thrombocytopenia
Incisor teeth, 31, 36
Inclusion body disease virus, 646
Incontinence, 395-397, 541
Indian tobacco toxicity, 120
Indian toothbrush, 140
Indirect bilirubin, 9
Indole glucosinolates, 149
Infarcts, necropsies and, 76
Infections, 343, 354-355, 359-360, 488. *See also Specific infections*
Infectious anemia, 439
Infectious bovine keratoconjunctivitis (IBK), 567
Infectious bronchitis, 605
Infectious bursal disease, 605-606
Infectious canine hepatitis (ICH), 267-268
Infectious coryza, 602
Infectious diseases. *See also* Bacterial infections; *Specific infectious diseases*
anemia, 439
birds and, 620-623
bovine keratoconjunctivitis (IBK), 567
bronchitis, 605
bursal, 605-606
camelid, 572
canine hepatitis (ICH), 267-268
canine infectious tracheobronchitis (ITB), 264, 357. *See also Bordetella* spp.
cetaceans and, 656
coryza, 602
enteric, 72-75
equine infectious anemia (EIA), 439
equine respiratory, 487-490
feline infectious respiratory disease, 263-264
ferrets and, 626, 627
hepatic, 241
laryngotracheitis, 606
marine mammals and, 650-651
meningoencephalitis, 280
orchitis-epididymitis, 344
pinnipeds and, 653
polyarthritis, 637
Infectious diseases *(Continued)*
stomatitis, 644
synovitis, 603
tracheobronchitis (ITB), 357
Infectious laryngotracheitis, 606
Infectious meningoencephalitis, 280
Infectious orchiditis-epididymitis, 344
Infectious polyarthritis, 637
Infectious stomatitis, 644
Infectious synovitis, 603
Infectious tracheobronchitis (ITB), 357
Infertility, 350-352, 551-552
Inflammation, 19-21, 251, 437, 468
Influenza
avian, 268, 604-605
equine, 444-445, 471, 488
ferrets and, 626
pinnipeds and, 653
swine, 596
vaccines for, 333t
Inguinal hernias, 505, 534, 534f, 658
Inhalation anesthetics, 404, 404t
Injections, 614-615, 643, 644f
Injection-site sarcomas, 301
Inotropic medication, 187
Inotropy, 165
Insect bites, 574
Insecticides, 132
Insulin, 15, 101
Insulin resistance, 220
Insulin therapy, 219
Insulin tolerance test (ITT), 431
Insulin-dependent diabetes mellitus (IDDM), 218
Insulin-like growth factor (IGF-1), 221, 222
Insulinoma, 220-221, 379, 626
Integumentary mycosis, 649
Interceptor, 336, 337t, 340
Interdigital fibroma, 550
Interdigital phlegmon (necrobacillosis), 550
Interleukin-1 (IL-1), 328
Intermediate density lipoproteins, 13-14
Internal papillomatosis, 621
Interstitial lung disease, 359
Intervertebral disk disease, 42
Intestines. *See also* Small intestine
birds and, 617
disorders of, 231-236, 232t
functional evaluation of, 11
necropsies and, 72-73
obstructions of, 236, 573-574
protothecosis of, 234
tumors of (equine), 463
viruses of, 265-267
Intramuscular administration, 614-615
Intraocular pressure (IOP), 84
Intrathoracic neoplasias, 363
Intravascular hemolysis, 414
Intravenous administration, fluid therapy and, 202-203

Intussusception, 49, 54, 228, 375-376, 375f, 503, 507
Ionized calcium (iCa), 214, 215t, 217t
Ionophore toxicosis, 559, 584
Ionophores, 112-113, 559
IOP. *See* Intraocular pressure
Ipomea toxicity, 138
Iris spp., 145
Iron, 126, 251, 290
Iron storage disease, 657, 658
Irritable bowel disease (IBD), 49, 56, 234-235, 295
Irritant contact dermatitis, 197, 421
Ischium, fractures of, 314
Isocupressic acid, 153
Isoflavone estrogens, 153
Isoflurane, 160t, 404t
Isoproterenol, 187
Isotonic dehydration, 4-5
ITB. *See* Infectious tracheobronchitis
ITP. *See* Idiopathic thrombocytopenic purpura
Iverheart, 336, 337t
Ivermectin milbemycin, 193
Ivermectins, 107-108, 135, 180, 181, 195, 282, 340
Ivomec, 336, 337t, 340

J

Jamestown weed, 139
Jejunal hemorrhage syndrome, 558
Jimson weed, 139
Johne disease, 74-75, 557, 582-583, 660
Joints, 42-43, 51-52, 523-524, 634, 635
Juglans nigra, 152
Juglonone, 152
Juvenile cellulitis (strangles), 199, 444, 471-472, 489-490
Juvenile head tilt, 565
Juvenile-onset polyarthritis syndrome, 330

K

Kaliopenic nephropathy-polymyopathy syndrome, 6
Kalmia spp., 115
Kappa receptors, 105
Karyolysis, 20
KCS. *See* Keratoconjunctivitis sicca
Kennel cough, 263-264, 333-334t, 336t, 659
Keratinization, 197-198, 422
Keratinocytes, 190
Keratitis, 86-88
Keratoacanthoma, 304
Keratoconjunctivitis (pinkeye), 465, 637
Keratoconjunctivitis sicca (KCS), 86
Keratocytes, 24
Ketamine, 158-159, 405, 406
Ketoacidosis, 220
Ketoconazole, 212-213
Ketones, 2
Ketosis, 563, 564-565
Kidney
 acute renal failure and, 386-389, 539
 acute tubular nephrosis and, 539-540
 birds and, 618-619
 calculi and, 657
 cetaceans and, 655, 657
 chemical evaluation of, 1-4, 3f, 4f
 chronic renal failure and, 384-385, 540
 clearance of (GFR), 1
 cysts of, 47
 diagnostic imaging of, 47-48
 diet and, 293
 disorders of, 379, 532
 drugs for, 101-102
 dysplasia of, 385
 failure of, 293, 384-389, 539, 540
 familial diseases of, 385
 ferrets and, 56
 fish and, 649
 glomerulonephritis and, 77-78, 385, 637
 glycosuria and, 385
 grapes and, 117, 388
 myoglobin and, 13
 necropsies and, 77-78
 nephrogenic diabetes insipidus (NDI) and, 222
 obstructions and, 389, 389f
 overview of, 101-102, 218
 polycystic, 77f, 78, 385
 primates and, 657-658
 progressive chronic kidney disease and, 385-386
 pyelonephritis and, 47, 78, 540-541, 567, 587
 reptiles and, 642
 rodents and, 639
 secondary hyperparathyroidism and, 433
 telangiectasia and, 385
 toxicants affecting, 117-121, 587
 tubulointerstitial disease and, 540
 tumors of (equine), 463
 ultrasonographic imaging of, 53-54
Kimzey leg savers, 521
Klamath weed, 152
Klebsiella spp., 482
Koalas, 664
Kochia scoparia poisoning, 127-128
Kremezin, 386
Kurloff bodies, 641

L

Labeling, pet food and, 291-292
Laboratory data, evaluation of, 16
Lacerations, 520-521, 537
Lactate dehydrogenase (LDH), 13
Lactation, 593
Lactic acidosis, 71, 556
Lactulose, 99, 100
Lagomorphs, dentistry of, 35, 35f
Laidlomycin, 112
LALP. *See* Liver origin alkaline phosphatase
Lameness, 517-519, 521, 549-550. *See also* Musculoskeletal system
Laminitis, 51, 51f, 426f, 432, 467-468, 526, 550
Langerhans cells, 190
Lantana spp. toxicity, 128
Large colon, 49, 231, 457, 507-511, 508f
Larkspur toxicity, 140
Laryngeal air sacculitis, 659
Laryngitis, 560
Laryngoplasty, 498, 498f
Laryngotracheitis, 606
Larynx
 diagnostic imaging of, 43
 disorders of, 353, 356, 382, 497-498, 498f
 necropsies and, 67
 tumors of (equine), 461
Laurel toxicity, 115
Lavage, 501, 513
Lawsonia intracellularis enteritis, 74
Laxative therapy, 237
LDDST. *See* Low-dose dexamethasone suppression test
LDH. *See* Lactate dehydrogenase
Lead toxicity, 131-132, 251, 281, 565, 589, 623
Left shift, 27
Leg mange, 419, 419f
Legg-Calves Perth Disease, 43, 315
Leiomyosarcomas, 301
Leishmaniasis, 251, 276, 665
Lenses, disorders of, 90-91, 90f
Lentiviruses, 590-591
Leprosy, 660
Leptocytes, 25
Leptospira spp.
 bovines and, 567
 erythrocytes and, 250
 pinnipeds and, 653
 reptiles and, 644
 rodents and, 637
 swine and, 597-598
 zoo animals and, 661
Leptospirosis, overview of, 271, 333t, 388
Leukemia
 basophilic, 254
 bovine, 562
 cavian, 641
 defined, 27
 eosinophilic, 254
 equine, 463

Leukemia *(Continued)*
feline, 250, 260-261
granulocytic (neutrophillic), 254
lymphoblastic, 253, 299-300
lymphocytic, 27, 253, 300
lymphoid, 253, 299-300
M_1, M_2 leukemia. *See* Acute myeloblastic leukemia
M_4 leukemia. *See* Acute myelomonocytic leukemia
M_5 leukemia. *See* Acute monocytic leukemia
M_6 leukemia. *See* Erythroleukemia
M_7 leukemia. *See* Megakaryoblastic leukemia
overview of, 253-254
vaccines for, 335t
Leukocytes, 24-28, 251-252
Leukoderma, 423
Leukotrichia, 423-424
Leydig cells, 81, 381, 480
Lice
bovines and, 564
camelids and, 574
drugs for, 108-110
overview of, 195, 419
pinnipeds and, 653
poultry and, 606-607
rodents and, 640
Lichenification, defined, 190
Lidocaine, 95, 186, 406, 412
Ligaments, injuries to, 520-521
Lighting, 600, 643
Lily toxicity, 121, 388
Limberneck, 609. *See also* Botulism
Lime sulfur dip, 195
Lincosamides, 103-104
Linford method, 425
Linognathus setosus, 195
Linum spp., 140-141
Lipase, 10
Lip-fold pyodermas, 34
Lipids, 13-14, 290, 292, 294
Lipomas, 304, 504-505
Lipopolysaccharides (LPS), 13-14
Liposarcomas, 300, 304
Lissencephaly, 282
Listeria monocytogenes, 59-60
Listeriosis, 59-60, 564, 589, 640
Little White Shaker syndrome, 281
Liver
abscesses of, 241
acute failure of, 240-241
birds and, 618
chemical evaluation of, 8-10, 9f
clostridial diseases and, 663
cysts of, 244, 637
diagnostic imaging of, 47
diet and, 294
disorders of, 239-246, 246f, 378-379
drugs for, 99-100
dysplasias of, 245
encephalopathies of, 100, 239, 240
Liver *(Continued)*
extrahepatic biliary obstruction and, 246
flukes, 241, 563, 572, 582
hepatic lipidosis and, 10, 76, 241, 294, 563, 574, 618
hepatitis and, 242-244, 267-268, 294, 659
hepatocutaneous syndrome and, 198
necropsies and, 76-77
portosystemic shunts (PSS) and, 244-245, 245f
rodents and, 637
ruminants and, 563
sheep, goats and, 583
toxicants affecting, 123-128
tumors of (equine), 463
ultrasonographic imaging of, 53
zinc and, 100
Liver origin alkaline phosphatase (LALP), 8
Llamas, 570-576
LMN disease. *See* Equine lower motor neuron disease
LMWH (low-molecular-weight heparin), 106-107
Lobular dissecting hepatitis, 243
Local anesthesia, ruminants and, 548-549
Locoism, 138
Locomotion, pinnipeds and, 651-652
Locust, 144
Loop colostomy, 513
Loop diuretics, 185-186
Lordosis, 656
Loriidae, 611. *See also* Birds
Low 4 point nerve block, 518, 518f
Low-dose dexamethasone suppression test (LDDST), 210
Lower motor neuron (LMN) disease, 453
LOX inhibitors, 105
Lufenuron, 110
Lumbosacral instability, 41
Lumbosacral space, 449, 449f
Luminal disease, 54
Lumpy jaw (actinomycosis), 554, 554f, 579
Lung
acute bovine pulmonary edema and emphysema and, 560
bronchopulmonary diseases and, 357-361, 358f
chronic obstructive pulmonary disease (COPD) and, 490-491, 491f
contusions, 360-361
diagnostic imaging of, 44
drugs for, 97-98
evaluation of, 486
failure of, 486-487
granulomatous pulmonary diseases and, 360
hemorrhage and, 44
Lung *(Continued)*
hypertension and, 183-184
hypoplasias, 553
lobe torsion, 44, 363
microlithiasis and, 44
necropsies and, 67-68
neoplasias, 361
obstructions and, 490-491, 491f
pulmonary edema and, 44, 360
pulmonary hypoplasia with anasarca (PHA) and, 553
pulmonary infiltrates with eosinophilia (PIE) and, 44, 360
respiratory tracts and, 490-491, 491f
stenosis, 44-45
strictures, 44-45
summer pasture associated obstructive pulmonary disease (SPAOPD), 490-491
thromboembolism and, 44, 183, 360, 363
tumors of, 383
Lungworms, 361, 473, 473t, 560, 653
Lupinus spp. toxicity, 139
Lupus, 198
Luteolysis, 351
Luxation
of carpus, 313-314
of coxofemoral joint, 315
of elbows, 312, 313f
of hip, 550-551
patellar, 316-317, 576
rabbits and, 634
of sacroiliac joint, 314
scapulohumeral, 310
of stifle, 317
of tarsal joint, 318-319
Lycopersican spp., 145
Lyme disease, 270-271
Lymphadenitis, 80, 640
Lymphadenopathies, 46
Lymphangiectasia, 73, 295
Lymphangiosarcomas, 301
Lymphatic system, 50, 67, 80, 298-300, 298t
Lymphoblasts, 29
Lymphocystitis, 648
Lymphocytes, 19, 21, 26, 29, 252
Lymphocytic cholangitis, 243
Lymphocytic choriomeningitis, 637
Lymphocytic leukemia, 27, 253, 300
Lymphocytic portal hepatitis, 243
Lymphocytic thyroiditis, 209
Lymphocytic-plasmacytic gastritis, 229-230
Lymphocytic-plasmacytic irritable bowel disease, 234-235
Lymphocytosis, 28, 252
Lymphoid leukemia, 253, 299-300
Lymphoid leukosis-sarcoma complex, 606
Lymphomas, 298-299, 298t, 462, 639, 659
Lymphopenia, 28, 252

Lymphoplasmacytic stomatitis, 33-34
Lymphoproliferative disorders, 27
Lymphosarcomas, 27, 80, 438, 462, 627f, 639
Lysichitum americanum, 145
Lysosomal storage disease, 251-252
Lyssaviruses, 666. *See also* Rabies

M

MAC. *See* Minimum alveolar anesthetic values
Macadamia nut toxicity, 113
Macaw wasting disease, 618, 622
Macrolides, 103, 181
Macrophages, 19-20, 29
Macrorhabdosis, 620
Macules, defined, 189
Mad cow disease, 63, 565, 668
Maduramicin, 112
Magnesium, 7, 141, 202, 290. *See also* Hypermagnesemia; Hypomagnesemia
Maidate, 159
Maintenance energy requirements, 291
Malaria, 657
Malassezia dermatitis, 196, 196f
Malignant catarrhal fever (MCF), 555
Malignant fibrous histiocytoma (MFH), 301
Malignant hyperthermia, 66
Malignant melanoma, 306, 371
Mallophaga, 419
Malocclusions, 573, 633, 638, 639, 640-641, 641f
Malunions, 328
Malus spp., 140-141
Mammary gland, 81, 302-303, 371
Manatees, 649-651
Mandibles, 305-307, 461, 634
Mane and tail dystrophy, 424
Manganese, 290
Mange
 camelids and, 574
 chorioptic, 419, 419f
 demodectic, 191, 191f, 421, 422, 639
 drugs for, 108-110
 notoedric, 196
 psoroptic, 419
 rabbits and, 630-631, 631f
 rodents and, 639
 sarcoptic, 196, 419, 597
Mannheimia haemolytica, 561
Mannitol, 101
Maples, 149
Marek disease, 606
Marestail, 140
Marine mammals, 649-657, 667
Mast cell tumors (MCT), 21-22, 300-302, 370-371, 461
Mast cells, 29
Masticatory muscle myositis, 35, 288
Mastitis, 56, 81, 549, 633, 640
Mastocytosis, 252
MATCHING DRAPES mnemonic, 217b
Maternal behavior, horses and, 408
Maxilla, 306-307, 461
MCH. *See* Mean corpuscular hemoglobin
MCHC. *See* Mean corpuscular hemoglobin concentrations
MCT. *See* Mast cell tumors
MCV. *See* Mean cell volume
M:E ratio. *See* Myeloid-erythroid ratio
Mean corpuscular hemoglobin (MCH), 24
Mean corpuscular hemoglobin concentrations (MCHC), 24, 26
Mean corpuscular volume (MCV), 24, 26
Measles, 333t
Meat Inspection Act, 56
Meconium, 512
Mediastinal disease, 54
Mediastinal shift, 46
Megacolon, 49, 237, 237f, 376
Megaesophagus, 71f, 226-227, 573, 579
Megakaryoblastic (M_7) leukemia, 254
Megakaryocytes, 29
Melanocytes, 190
Melanocytic tumors, 423
Melanomas, 304, 460-461, 516
Melarsomine, 108, 180, 181
Melilotus sp., 128, 150, 153
Meloxicam, 406
Membranoproliferative glomerulonephritis, 385
Menace response, 93
Meningeal worms, 571, 590
Meningiomas, 280
Meningitis, 286
Meningoencephalitis, 280, 565, 657
Meniscus, problems of, 317
Meperidine, 157-158
Mera "F" systems, 156
Merosin, 287
Mesenchymal cells, 21
Mesenteric volvulus, 49
Mesoesophagus, 48-49, 48f
Mesotheliomas, 182
Mesotocin, 619
Metabolic bone disease, 669-670
Metabolic syndrome, 431-432
Metabolism, skin disorders and, 197-198
Metacarpal fractures, 319, 427-428
Metacarpo-tarsophalangeal joint, 427, 527
Metaldehyde toxicity, 129, 282
Metamyelocytes, 26
Metaphyses, 325-326
Metarubricytes, 28
Metastatic bone tumors, 302
Metatarsal fractures, 319
Methemoglobinemia, 251
Methimazole, 100
Methionine, 292
Methoprene, 110
Methyl indole toxicity, 123
Methylene blue stain (new), 19
4-Methylimidazole toxicity, 130, 565
Methylxanthines, 97, 130-131, 281
Metoclopramide, 98
Metoprolol, 95
Metritis, 347, 482, 552, 576, 639
Metronidazole, 100, 103, 282
Mexiletine, 95
Mexilitine, 186
MFH. *See* Malignant fibrous histiocytoma
Mice, 636-637
Microcystin, 125
Microfilaria tests, 179, 338
Microfilariacidals, 180, 340
Microhepatia, 47
Microsporum canis, 194, 335t
Midazolam, 157
Milbemycin, 108, 180, 181, 195
Milk fever, 7-8, 216-218, 217b, 217t, 551, 578
Milk tetany, 7
Milkweed toxicity, 114
Milrinone, 97
Mineralocorticoids, 101
Minerals, 290, 458, 577-578
Minimum alveolar anesthetic (MAC) values, 160, 160t
Mink transmissible encephalopathy, 668
Mirror images, 53
Miserotoxin, 137-138
Misoprostol, 98
Mistletoe, 145-146
Mitaban, 136, 192
Mites. *See also* Demodicosis
 drugs for, 108-110
 ear, 627, 630
 ferrets and, 627
 poultry and, 607
 rabbits and, 630, 631f
 reptiles and, 645
 rodents and, 638, 640
 skin disorders and, 195-196, 195f, 419, 419f
Mitochondrion myopathy, 288
Mitotane, 100, 212
Mitral valves, 45, 169-170, 410, 412
Mixed sarcoids, 515
MLV. *See* Modified-live vaccines
Mobitz type blocks, 185
Modified Knott test, 179, 181
Modified water deprivation test, 222
Modified Whitehouse approach, 496
Modified-live vaccines (MLV), 470
Molar teeth, 31
Moldy corn poisoning, 134

Monensin, 112
Monkeypox, 667
Monkshood toxicity, 115
Monocytes, 26, 28, 29, 252
Monocytosis, 28, 252
Monofilament sutures, 368
Monstera spp., 145
Monteggia fractures, 311
Moon blindness, 465-466
Morbilliviruses, 445, 656
Morning glories, 138
Morphine, 105, 157, 164
Mosquitoes, 178. *See also* Heartworm disease
Motility, gastric, 230
Motion mode (M-mode), 53
Motor neuron disease, 453-454
Mouth, 152, 456, 617
Mouth rot, 644
Moxidectin, 135, 181
MR. *See* Mitral regurgitation
MRM. *See* Murine respiratory mycoplasmosis
Mu receptors, 105
Mucoceles, 225-226, 245-246, 371-372
Mucosal disease, 554
Multifilament sutures, 368
Multiple cartilaginous exostosis, 323
Multiple myeloma, 254, 300
Multiple renal cystadenocarcinomas, 385
Multisystem neuroaxonal dystrophy, 283
Mural disease, 49, 54
Murine respiratory mycoplasmosis (MRM), 636, 637
Murmurs, 411-412, 559
Muscles. *See also* Skeletal muscle
 chemical evaluation of, 12f, 13
 masticatory, 35, 288
 neurologic disorders and, 287-289
 skeletal, 111-117, 320-321
 surgery of, 320-321
 toxicology and, 111-117
Muscular dystrophies, 287-288
Musculoskeletal system
 chemical evaluation of, 12f, 13
 disorders of (equine), 517-532
 muscle surgery and, 320-321
 necropsies and, 65-66
 ruminants and, 549-551
 toxicants affecting, 111-117
 tumors of (equine), 463-464
 ultrasonographic imaging of, 55
Mushroom toxins, 63
Mustards, 149
Muzzles, 365, 366, 366f
Myasthenia gravis, 288-289
Mycobacteriosis, 272
Mycobacterium spp., 649, 660
Mycoplasma spp.
 anemia and, 26, 249
Mycoplasma spp. *(Continued)*
 bovine respiratory disease and, 562
 camelids and, 572
 pinnipeds and, 653
 poultry and, 603
 reptiles and, 647
 rodents and, 636
 swine and, 595
Mycoses
 abortion and, 82
 corneal, 87, 87f
 cytology of, 22-23
 drugs for, 104
 of feet and hooves, 524-525
 ferrets and, 626
 gutteral pouch, 496
 osteomyelitis and, 327
 overview of, 665-666
 pneumonia and, 44
 poultry and, 608
 rhinitis, sinusitis and, 355
 rumenitis and, 71, 71f
 skin and, 421
 superficial, 631
 systemic, 272-275
Mycotoxins, 124-125, 129, 142, 152-153, 543-544
Myelitis
 equine protozoal (EPM), 440-442, 450-451, 450f
 granulomatous meningoencephalomyelitis (GME), 280
 herpes, 452
 osteo-, 51, 52f, 327-328
 overview of, 285, 286-287
 verminous, 451-452
Myelodysplastic syndrome, 253
Myelofibrosis, 254
Myeloid leukemias, 463
Myeloid malignancies, 253
Myeloid-erythroid (M:E) ratio, 30
Myelonecrosis, 251
Myelophthisis, 251
Myeloproliferative disorders, 27, 80, 254
Myiasis, 631, 647
Myocardial diseases, 45-46, 171-176, 172f, 173f, 175f, 627
Myocarditis, 70, 413
Myocardium, 69, 410
Myodegeneration, 584
Myoglobin, 13
Myonecrosis, 551
Myopathy, fibrotic, 521
Myositis
 clostridial, 66, 656, 664
 dermato-, 199, 288
 masticatory muscle, 35, 288
 polyarthritis-polymyositis, 330
Myotonia congenital, 288, 455
Myxedema, 194
Myxosarcomas, 301

N

N_20. *See* Nitrous oxide
NAG. *See* N-Acetyl-β-D-glucosaminidase
Naked nuclei-neuroendocrine, 22
Naloxone, 106
Narasin, 112
Narcissus spp., 145
Narcotics, 436
Nasal cavity, disorders of, 353
Nasal passages, 461, 585
Nasitrema, 656
Nasogastric tubes, 203, 203f
Nasolacrimal ducts, 643
Nasopharyngeal polyps, 42, 355, 382
Nausea and vomiting, 98, 229, 627
Navicular bone, 51, 52f
Navicular disease, 51, 52f, 426, 427, 526
Navicular osteomyelitis, 51, 52f
NDI. *See* Nephrogenic diabetes insipidus
Necropsy
 cardiovascular system and, 69-70
 central nervous system and, 82-83
 endocrine system and, 79-80
 external examination, 65
 gastrointestinal tract and, 70-75
 hematopoietic system and, 80
 liver, biliary system and, 76-77
 musculoskeletal system and, 65-66
 pancreas and, 79
 reproductive tract and, 81-82
 respiratory system and, 66-69
 urinary tract and, 77-79
Necrosis, 43, 251, 315, 551, 589, 649
Necrotic enteritis, 559, 603-604
Necrotic laryngitis, 560
Necrotizing encephalitis, 280-281
Necrotizing vasculitis, 281
Negative diagnostic likelihood ratio (NLDR), 16
Negative predictive value (NPV), 16
Nemaline rod myopathy, 288
Nematodes, 571, 582, 590, 649
Neomycin, 100
Neonatal colibacillosis, 73
Neonatal conjunctivitis, 85
Neonatal diarrhea, 580
Neonatal isoerythrolysis, 417
Neoplasias
 of axial skeleton, 309
 birds and, 616, 618-619
 of bladder, 380-381
 of colon, 376
 cytology and, 21-22
 diagnostic imaging of, 40, 42, 43, 44, 48
 enteric, 75
 equine, 423, 437-438, 459-464

Neoplasias *(Continued)*
esophageal, 228-229, 372
exocrine pancreatic, 247
eyelid, 85
ferrets and, 626-627
gastric, 231, 374
hepatobiliary, 244
hypercalcemia and, 8
intestinal, 236, 370-371, 376
laryngeal, 356
of liver, 77, 78
lymphoid, 298-300, 298t
mammary, 302-303
marine mammals and, 651
of maxilla and mandible, 306-307
nasal, 355-356, 585
necropsies and, 68
nervous system and, 280, 283-284
of oral cavity, 371
orbital, 85
ovarian, 347, 477
pelvic, 309
penile, prepuce, 346, 536
pericardial disease and, 182
pinnipeds and, 654
plasma cell, 300
primates and, 659
principles of, 297
prostatic, 343, 381
pulmonary, 361
renal, 389-390
reptiles and, 646
of ribs, 309
rodents and, 636
skeletal, 302
testicular, 344-345, 534-535
thoracic, 321-322, 363
tonsillar, 225
urinary and, 79, 398-399, 400
uterine, 347-348
vaginal, 350
of vertebrae, 309
Neoricksettiosis, 75, 269-270
Neospirosis, 275-276
Nephrectomy, 379
Nephritis, 77-78, 385, 637
Nephrocalcinosis, 638
Nephrogenic diabetes insipidus (NDI), 222
Nephropathy, obstructive, 389, 389f
Nephrosis, 539-540
Nephrotoxins, 386-387
Nerium spp., 113-114
Nerve blocks, 518, 518f
Nervous coccidiosis, 565
Nervous system. *See also* Peripheral nervous system
clostridial diseases and, 663-664
diagnostic approach for, 277-279
disorders of in sheep and goats, 588-591
disorders of in swine, 596
Nervous system *(Continued)*
equine disorders of, 440-443, 449-453, 450f
evaluation of, 447-449, 449f
necropsies and, 82-83
neurologic evaluation and, 278
ophthalmology and, 92-93, 93f
rabbits and, 634-635
reptiles and, 646
rodents and, 637, 638, 639, 640
ruminants and, 564-567
sheep, goats and, 588-589
toxicants affecting, 128-141
Nesting, 620
Nestlings, 623
Neuroblastomas, 79
Neurofibrosarcomas, 301
Neuromuscular junctions, 287-289
Neuro-ophthalmology, 92-93, 93f
Neuropathic pain, defined, 163
Neuropathies, 287
Neurotoxins, 63, 281-282
Neutropenia, 28, 252, 656
Neutropenia with left shift, 28
Neutrophilia, 235, 252
Neutrophilic (suppurative) enterocolitis, 235
Neutrophilic cholangitis, 243
Neutrophils, 19-20, 25-26, 243, 252
New methylene blue stain, 19
Newcastle disease, 604
Niacin, 291, 292-293
Nicotine toxicity, 134-135
Nictitating membrane, 84, 86
NIDDM. *See* Non-insulin dependent diabetes mellitus
Nigropallidal encephalomalacia, 137
Nitenpyram, 109
Nitrate toxicity, 146-147
Nitrite toxicity, 146-147
Nitroglycerin, 94
Nitroglycerine ointment, 188
Nitrous oxide (N_2O), 155, 159, 161, 404
NLDR. *See* Negative diagnostic likelihood ratio
Nociception, 163, 278
Nodular cortical hyperplasia, 79
Nodular skin disorders, 199-200
Nodularin, 125
Nodules, defined, 189
Noncardiogenic pulmonary edema, 360
Noncore vaccines, 332
Nondihydropyridines, 186
Nonerosive arthritis, 329-330
Non-insulin-dependent diabetes mellitus (NIDDM), 218
Nonprotein nitrogen (urea) toxicosis, 132
Nonrebreathing coaxial systems, 156
Nonregenerative anemias, 26, 27
Nonsteroidal antiinflammatory drugs (NSAIDs).
acute primary (intrinsic) renal failure and, 389
colic and, 436
osteoarthritis and, 329
overview of, 105
pain and, 164
toxicity from, 143
Nonsweating, 433-434
Nonunion, 328
Norepinephrine, 187
Normocytic, defined, 24
Norovirus, 62
Norwalk virus, 62
Notoedres cati, 196
Notoedric mange, 196
NPV. *See* Negative predictive value
NSAIDs. *See* Nonsterodal antiinflammatory drugs
Nuchal crests, 305
Nuclear cardiography, 165
Nuclear scintigraphy, 500
Nuclear sclerosis, 90
Nursing, foals and, 408
Nutrition. *See also* Food safety
birds and, 611
camelids and, 570-571
diseases and, 293-296
dysplasias and, 253
energy requirements and, 291
equine, 456-458, 472
erythrocytes and, 251
ferrets and, 627
fish and, 648
hyperparathyroidism and, 218
marine mammals and, 650
metabolic bone disease and, 669-670
oncology principles and, 297
overview of, 290-291
parathyroidism and, 468
pinnipeds and, 652
poultry and, 599-600, 608-609
primates and, 657, 658, 659
rabbits and, 629
reptiles and, 643, 646, 647
rodents and, 636, 639
sheep, goats and, 577-578
unique to cat, 292-293
Nutritional myodegeneration, 584
Nuts, 113, 138, 152

O

Oak poisoning, 120-121, 587
Obesity, 293
Obstructions. *See also* Volvulus
cetaceans and, 657
equine, 404-405, 436-437, 438, 438f
esophageal, 501
extrahepatic biliary, 246
gastric outflow, 230
intestinal, 236, 573-574
kidneys and, 389, 389f
periesophageal, 228

Obstruction. *(Continued)*
pulmonary disease and, 490-491, 491f
reptiles and, 644
small colon, 511-512
urethral, 397-398, 533-534
urolithiasis and, 541
OC. *See* Osteochondrosis
Occult sarcoids, 515
OCD. *See* Osteochondritis desiccans
Ocular motility, 277-278
Ocular position, 277
Ocular reflexes, 92-93
Ocular squamous cell carcinoma, 567
Odontomas, 307
Odoroside, 113
Oesophagostomum, 75
Ohio buckeyes, 138
Oil exposure, 653-654, 657
Oleander toxicity, 113-114
Oleandomycin, 113
Olecranon fractures, 311, 428
Omental Cushing syndrome, 431
Omphalophlebitis, 541, 541f
Onions, 148-149
Onychectomy, 320
Ophthalmology
anatomy of, 84
equine, 465-466
overview of, 84-93, 85f, 86f, 90f, 93f
pinnipeds and, 652, 654
primates and, 658
reptiles and, 643, 646
rodents and, 636-640
ruminant, 567
Opioid agonist-antagonists, 402
Opioid analgesics, 105-106, 406
Opioids, 99, 157-158, 164
Opossums, 450
OPP. *See* Ovine progressive pneumonia
Optic neuritis, 92
Oral cavities, 70, 225-226, 499-501
Orbits, 84-85
Orchidectomy, 345
Orchitis, 81, 344, 481, 620
Organophosphates, 108-109, 132-133, 282
Oronasal fistulas, 225
Oropharyngeal cavity, 152, 226
Orthopox viruses, 268, 666-667
OSA. *See* Osteosarcomas
Oscillatoria spp., 125-126, 133-134
Osmolal gap, 5-6
Osmolality, 5-6, 202
Osteitis, pedal, 51, 425, 426f
Osteoarthritis (OA), 328-329, 519, 527, 530
Osteoarthropathy, 496
Osteoblasts, 29
Osteochondral fragments, 428, 530
Osteochondritis, 427
Osteochondritis desiccans (OCD), 43, 324-325, 325f, 427
Osteochondrosis (OC), 43, 52, 324-325, 325f, 523, 527, 531
Osteoclasts, 29
Osteomalacia, 66, 669
Osteomyelitis, 51, 52f, 327-328
Osteomyelosclerosis, 616
Osteopathies, 35, 42, 323
Osteopenia, 669
Osteopetrosis, 251
Osteosarcoma (OSA), 66, 302, 321, 371
Osteotomies, 315
Otitis externa, 42, 200
Otitis interna, 200
Otitis media, 42, 200, 636, 637, 639
Ovarian remnant syndrome, 346-347, 381
Ovariohysterectomy, 348, 382
Ovary
anatomy of, 348f
birds and, 619-620
diagnostic imaging of, 50, 54
disorders of, 346-348, 476-477, 476f, 537-538, 553
evaluation of (equine), 475
necropsies and, 81
Overeating disease, 663
Oviducts, 620
Ovine lentivirus (OvLV), 586, 590
Ovine management and husbandry, 577-591
Ovine progressive pneumonia (OPP), 586
Oviposition, 619
OvLV. *See* Ovine lentivirus
Ovulation, induction of, 352, 479
Oxalates, 120, 121, 587
Oxalis spp., 120
Oxygen, 205, 404, 648
Oxygen cylinders, 155
Oxygen flow meters, 155
Oxymorphone, 105-106, 158
Oxytocin, 480
Oxytropis spp. (locoweed), 137-138

P

PA toxicity, 127
Pacemakers, 185
Pacheco disease, 621
Packed-cell volume (PCV), 24
Pain
aggression and in horses, 407
anesthesia and, 163-164
definitions of, 163
oncology principles and, 297
signs of acute in horses, 406
Paintballs, 135
Pale foci, 640
Palmaromedial eminence, 426
Palmar-plantar digital nerve block, 518, 518f
Palpebral reflexes, 93, 278
Pancreas
birds and, 619
chemical evaluation of, 10-11
diagnostic imaging of, 50
diet and, 295
disorders of, 246-247, 379
exocrine pancreatic insufficiency (EPI) and, 11, 247, 295
necropsies and, 79
pancreatitis and, 79, 217-218, 246-247, 295, 363, 379
ultrasonographic imaging of, 55
Pancreatitis, 79, 217-218, 246-247, 295, 363, 379
Pancreatitis-associated effusion, 363
Panleukopenia, 75, 266, 334t
Panosteitis, 41, 41f, 322
Pantothenic acid, 291
Papanicolaou stain, 19
Papilledema, 92
Papillomatosis, 268, 303, 422-423, 564, 621, 656
Papillomatous digital dermatitis, 550
Papillomaviruses, 268, 650
Papules, defined, 189
Parainfluenza viruses, 333t
Paralysis, 283, 405, 454, 639, 641
Paramedial clefts, 642
Paramedian abomasopexy, 547
Paramyxoviruses, 604, 646
Paraphimosis, 346, 381, 535
Parapoxvirus, 667
Paraprostatic cysts, 343
Paraquat toxicity, 122
Parasites
antiparasitic agent toxicity and, 135
bovine, 545
camelids and, 571-572
cetaceans and, 656
crustacean, 649
diarrhea and, 232-234
equine, 472-474, 473t
erythrocytes and, 26-27
fecal, 11
ferrets and, 627
fish and, 649
food-born illnesses and, 62-63
marine mammals and, 651
necropsies and, 72
pinnipeds and, 653
pneumonia and, 560
poultry and, 606-607
prevention of, 107-110, 135
primates and, 657, 658, 659
reptiles and, 644, 647
respiratory system and, 361
rhinitis, sinusitis and, 355
rodents and, 636-638, 640
sheep, goats and, 582, 585, 590
skin disorders and, 194-196
swine, 594-595

Parathyroid gland
birds and, 619
calcium metabolism and, 214
disorders of, 433
hyperparathyroidism and, 8, 218, 433, 468, 646
necropsies and, 80
Parathyroid hormone (PTH), 214, 215t, 217t, 433
Paratuberculosis, 74-75, 557, 582-583, 660
Paraurethral cysts, 56
Parelaphostrongylus tenuis, 571, 590
Parietal sulcus, 425
Parrot mouth, 499
Parrots, 611, 621. *See also* Birds
Pars intermedia adenoma, 79
Pars intermedia dysfunction (PID), 429-431, 429f
Partial barium enemas, 50
Parturition induction, 480, 592
Parvoviruses, 75, 172, 265, 333t, 597, 626
Pastern dermatitis, 422
Pastern folliculitis, 421
Pastern joints, overview of, 427
Pasteurellosis, 602, 632, 653
Pasteurization, 56
Pasture breeding, 482
Pasturella multocida, 561
Patches, defined, 189
Patellar luxation, 43, 316-317, 576
Patellas, 531-532
Patent ductus arteriosis (PDA), 44-45, 165, 166t, 167-168
Patent urachus, 78, 533, 541, 541f
Pathogens, USDA and, 57
PBD. *See* Proliferative bowel disease
PBFD. *See* Psittacine beak and feather disease
pCa. *See* Protein-bound calcium
PCV. *See* Packed-cell volume
PDA. *See* Patent ductus arteriosis
PDD. *See* Proventricular dilation disease
Pectineal myectomy, 316
Pedal osteitis, 51, 425, 426f
Pedal bone, 51
Pediculosis, 195, 419
Pedunculated lipomas, 504-505
Pelger-Huet anomaly, 251
Pellets, 611
Pelvis, 309, 314, 532
PEM. *See* Polioencephalomalacia
Pemphigus complex, 198
Pemphigus erythematosus, 198
Pemphigus foliaceus, 198, 421-422
Pemphigus vulgaris, 198
D-Penicillamine, 100
Penicillin, 100, 102, 129
Penis, 81-82, 345-346, 481-482, 535-536, 640
Pentastomids, 644
Pentitol, 126
Pentitrem A toxicity, 129
Pentobarbital, 158
Perennial ryegrass staggers, 134
Perforation, esophageal, 227
Pergolide, 431
Perianal glands, 238-239, 303
Periapical infections, 500
Periarterial venous retes, 655
Pericardial disease, 46f, 182-183
Pericardial effusion, 182
Pericardiocentesis, 183
Pericardium, 69, 410
Periesophageal obstruction, 228
Periglomerular fibrosis, 385
Perimysium, 320
Perinephric pseudocysts, 47
Perineum, 237-238, 369, 378, 537
Periodontal disease, 32-33, 42
Periodontal ligament, 31-32
Periorbital disease, 466
Peripheral nervous system
disorders of, 287, 453-455, 566-567
evaluation of, 447-449
neurologic evaluation and, 278
Peritoneal fluid, 11
Peritoneopericardial diaphragmatic hernias, 182
Peritonitis, 247, 375, 620
Peroneal nerves, 566-567
Persea americana, 117
Persistent corpus luteum, 575
Persistent penile frenulum, 346
Persistent right aortic arch (PRAA), 228, 228f
Pesticides, 130, 132-133, 136
Pesudorabies, 267
Petrolatum, 99
PFTE. *See* Polytetrafluoroethylene
pH, 2. *See also* Acid-base metabolism
PHA. *See* Pulmonary hypoplasia with anasarca
Phalanges, 319
Pharynx, 67, 461
Phaseolus limensis, 140-141
Phenobarbital, 107, 244, 286
Phenothiazines, 98, 402
Phenoxy herbicides, 142-143
Phenoxybenzamine, 102
Phenylbutazone, 406
Phenylpropanolamine, 102
Pheochromocytomas, 79, 223
PHF. *See* Potomac horse fever
Philodendron spp., 145
Phimosis, 346, 381, 535
Phobias, horses and, 409
Phoradendron seratonium, 145-146
Phosphate binders (intestinal), 385
Phosphodiesterase inhibitors, 97
Phosphofructokinase deficiency, 249
Phosphorus, 1-2, 7, 202, 290. *See also* Hyperphosphatemia; Hypophosphatemia
Physes, 325-326, 326f
Physical restraint, 493
Physitis, 524
Phytohaemagglutinin, 63
PID. *See* Equine cushing-like syndrome
PIE. *See* Pulmonary infiltrates with eosinophilia
Pieristoxins, 115
Pigmentary disorders, 423-424
Pigweed toxicity, 121
Pimobendan, 97, 187, 187t
Pine toxicity, 153
Pink eye, 567
Pinnipeds, 651-654
Pinworms, 473, 473t, 637, 638, 640
Pironolactone, 94
Piroplasmosis, 440
Pituitary gland, 79, 210, 429, 432
Placentas, retained, 552, 576
Plague, 272, 662
Plant toxicities, 584-585, 587. *See also* Toxicology
Plaques, defined, 189
Plasma, serum vs., 11-12
Plasma cell neoplasia, 300
Plasma cell pododermatitis, 199
Plasma cells, 19, 29
Plasma proteins, 11-12
Plasma turbidity tests, 11
Plasmacytomas, 300
Platelet concentration, 24
Platelets, disorders of, 252-253, 417-418
PLDR. *See* Positive diagnostic likelihood ratio
Pleural effusions, 46, 54, 68-69, 362, 657
Pleuropneumonia, 595
Pneumediastium, 46
Pneumocolon, 50
Pneumogastrograms, 49
Pneumonia
atypical interstitial, 561
broncho-, 359-360, 488
camelids and, 575
cetaceans and, 656
diagnostic imaging of, 44
equine, 443-444
gram-negative bacteremia with, 487-488
necropsies and, 68
parasitic, 560
pinnipeds and, 653
primates and, 657, 658, 659
rabbits and, 631-632
reptiles and, 644
rodents and, 636-640
sheep, goats and, 585-586
swine, 595
Pneumonic plague, 662
Pneumothorax, 46, 361-362, 362f

Pneumovagina, 536
Pododermatitis, 192, 199, 631, 640, 640f, 641. *See also* Bumblefoot
Poikilocytosis, 24, 25f
Poinsettia toxicity, 145
Poison hemlock, 139-140
Poison weed, 140
Polioencephalomalacia (PEM), 565, 573, 589-590
Polioviruses, 637
Polyarthritis, 330, 637
Polychromasia, 25
Polycystic kidneys, 77f, 78, 385, 638
Polycythemia vera, 254
Polycythemias, 27, 251, 254
Polydactyly, 41
Polymer-fume fever, 122-123
Polyneuritis equi, 452
Polyneuropathies, 287
Polyoma, 621
Polyps, 238, 355
Polytetrafluoroethylene (PFTE) toxicity, 122-123
Pop-off valves, 156
Porcine circovirus (PCV-2)-associated disease, 596
Porcine parvovirus (PPV), 597
Porcine proliferative enteropathy (PPE), 594
Porcine reproductive and respiratory syndrome (PRRS), 596, 597
Porphyria, 249
Portal hypertension, 294
Portosystemic shunts (PSS), 9f, 10, 244-245, 245f, 294, 378-379, 378f
Positive diagnostic likelihood ratio (PLDR), 16
Positive inotropic medication, 187
Positive predictive value (PPV), 16
Postanesthetic myopathies, 455
Postcaval syndrome, 560
Posterior pituitary dysfunction, 432
Postexposure prophylaxis, 666
Postrenal azotemia, 384
Postural reflexes, 277
Potassium. *See also* Hyperkalemia; Hypokalemia
 electrolyte metabolism and, 6-7
 fluid therapy and, 202
 kidneys and, 1, 102, 386
 as nutrient, 290
Potassium channel blockers, 186
Potassium-sparing diuretics, 186, 186t
Potomac horse fever (PHF), 75, 269-270, 472
Poultry, 599-609
Poxviruses
 avian, 605, 667
 caiman, 647
 cetaceans and, 656
 cowpox, 268, 666-667
 dolphin pseudopox, 653
 feline, 268
Poxviruses *(Continued)*
 goat pox, 579
 monkeypox, 667
 orthopox, 268, 666-667
 overview of, 666-668
 parapox, 667
 seal, 653
 sheep, 579
 swine, 597
PPE. *See* Porcine proliferative enteropathy
PPV. *See* Porcine parvovirus; Positive predictive value
PPVH. *See* Primary portal vein hypoplasia
PRA. *See* Progressive retinal atrophy
PRAA. *See* Persistent right aortic arch
Praziquantel, 107
Prazosin, 95
Preanesthesia, 156-158
Precision vaporizers, 155-156
Prednisone, 101, 299
Preemptive analgesia, 163
Pregnancy. *See also* Estrous cycle
 camelids and, 575
 diagnosis of, 351
 equine, 483-484
 maintenance of, 480
 swine, 592
 toxemia and, 563, 583, 641
 ultrasonographic imaging of, 54
 uterine diseases and, 347
Preload, defined, 165
Premature beats, 184
Prematurity, 486-487, 487f
Premolar teeth, 31
Prepuce, 81-82, 345-346, 481, 535-536
Prerenal azotemia, 384
Priapism, 346, 535-536
Primary ciliary dyskinesia, 354
Primary portal vein hypoplasia (PPVH), 245
Primary sphincter mechanism incompetence (PSMI), 396
Primary thrombocythemia, 254
Primates, 657-659, 660
Prion disease, 63
Procainamide, 95, 186, 412
Proctitis, 237
Proctodeum, 618
Production medicine, 546-547
Proestrus, 350-352
Progestogens, 480
Program, 338
Progressive retinal atrophy (PRA), 91
ProHeart, 336, 337t
Prokinetic agents, 98
Prolactin, 619
Prolapse
 anorectal, 237
 birds and, 620
 cloacal, 618, 645
Prolapse *(Continued)*
 primates and, 658
 rectal, 56, 376, 513-514, 583
 reptiles and, 645
 urethral, 400
 uterine, 347, 553
 vaginal, 350, 553-554, 588
Proliferation, wound healing and, 514
Proliferative bowel disease (PBD), 56
Proliferative disorders, defined, 27
Proliferative urethritis, 399-400
Prolonged estrus, 351
Propanolol, 95, 186
Prophylaxis, wounds and, 368
Propofol, 159, 403
Propranolol, 412
Proprioception, 277
Propylene glycol, 118-120
Prorubricytes, 28
Prosimians, 657-658
Prostaglandins, 479, 480
Prostate glands, 50, 54, 56, 81, 342-343
Prostatitis, 54, 81
Protein, 2, 290, 292
Protein-bound calcium (pCa), 214, 215t, 217t
Protein-losing enteropathy, 235, 295
Proteoglycans, 328
Prothrombin time (PT), 255
Protothecosis, 234
Protozoans, 82, 233-234, 275-276, 607-608, 637. *See also* Sarcocystosis
Proventricular dilation disease (PDD), 618, 622
Proventriculus, 617
Proximal sesamoid bones, 427, 527-528
PRRS. *See* Porcine reproductive and respiratory syndrome
Prunus spp., 140-141
Pruritic skin disorders, 194-197, 195f, 196f, 419-420, 419f, 420f
Prussian blue stain, 19
Pseudocoprostasis, 238
Pseudohermaphroditism, 344, 381, 481
Pseudohyponatremia, 6
Pseudomoniasis, 661-662
Pseudorabies, 267, 566
Psittacidae, 611. *See also* Birds
Psittacine beak and feather disease (PBFD), 621-622
PSMI. *See* Primary sphincter mechanism incompetence
Psoroptic mange, 419
PSS. *See* Portosystemic shunts
PT. *See* Prothrombin time
Pteridium aquilinum, 150
PTH. *See* Parathyroid hormone
Puberty, 480
Pubis, fractures of, 314
Puerperal metritis, 552
Puerperal tetany, 217

Pufferfish poisoning, 64
Pulmonary diseases, 54-55, 357-361, 358f, 490-491, 491f
Pulmonary edema, 44, 360
Pulmonary hemorrhage, 44
Pulmonary hypertension, 183-184
Pulmonary hypoplasia with anasarca (PHA), 553
Pulmonary infiltrates with eosinophilia (PIE), 44, 360
Pulmonary microlithiasis, 44
Pulmonary thromboembolism, 44, 183, 360, 363
Pulmonic stenosis, 45, 166t, 168-169, 168f
Pulp, 31, 36
Pulp chambers, 499
Pulse oximetry, 162
Pulse strength, 161
Pupillary light reflexes, 277
Puppy strangles, 489-490
Pustules, defined, 189
Putrefactive disease, 649
Pyelonephritis, 47, 78, 540-541, 567, 587
Pyknosis, 20
Pyodermas, 34, 193
Pyogranulomatous inflammation, 20
Pyometra, 54, 56, 347, 381
Pyothorax, 69, 362-363
Pyrantel, 107
Pyrethrins, 108, 133
Pyrethroids, 108, 133
Pyridoxine, 293
Pyrrolizidine alkaloid poisoning, 63, 127
Pyruvate kinase deficiency, 249
Pythiosis, 234, 422, 516-517, 666
Pythium insidiosum, 234
Pyuria, 3

Q

Quail disease, 604
Quarantine, 649
Quercus spp., 120-121, 587
Quinidine, 95, 186, 412

R

RAAS. *See* Renin angiotensin aldosterone system
Rabbits, 629-635
Rabies
 bovine, 565-566
 equine, 442
 ferrets and, 626
 overview of, 267, 666
 vaccines for, 334t, 335t, 472
RAD. *See* Recurrent airway disease
Radial head, 311
Radial nerve, 566
Radiography, 425-428, 426f, 612-614, 643
Radioiodine, 100
Radiotherapy, 297
Radius, 311-312, 530
Rain rot/scald, 420, 420f, 564
Raisins, 117, 388
Range paralysis, 606
Ranunculus spp., 144
Raphanus spp., 149
RAS. *See* Renin-angiotensin system
Rats, 636, 637-638
RBC. *See* Red blood cells
RD. *See* Retinal dysplasia
RDW. *See* Red cell distribution width
Rebreathing bags, 156
Reciprocal apparatus, 521
Rectal examinations, 493
Rectovaginal fistulas, 238
Rectum, 56, 377-378, 512-514, 583
Recurrent airway disease (RAD), 490-491, 491f
Red blood cells (RBC), 3, 24-25, 655
Red cell distribution width (RDW), 24
Red maple leaves, 415-416
Red tide, 651
Redmouth, 649
Redworms, 472, 473t
Reference ranges, 16
Referred pain, 163
Reflexes, 92-93, 162-163, 277, 278
Refractometers, 12
Refrigeration test, 14
Regeneration, wound healing and, 514
Regenerative anemias, 26, 414
Regional granulomatous enterocolitis, 235
Regulatory bodies, 56-57
Regurgitation, 618, 644
Reinduction and Rescue therapy, 299
Remodeling, wound healing and, 514
Renal calculi, 657
Renal clearance (GFR), 1
Renal cysts, 47
Renal disease, 101-102, 218
Renal dysplasia, 385
Renal failure, 293, 384-389, 539, 540
Renal glucosuria, 385
Renal secondary hyperparathyroidism, 433
Renal system. *See* Kidneys
Renal telangiectasia, 385
Renin angiotensin aldosterone system (RAAS), 165
Renin-angiotensin system (RAS), 213
Repair, wound healing and, 514
Reproductive tract
 anemia and, 251
 birds and, 619-620
 breeding management and, 482-484, 484f
 camelids and, 575-576
 cetaceans and, 655
 dermatoses and, 194
Reproductive tract *(Continued)*
 diagnostic imaging of, 48-49, 50
 disorders of, 429-434
 disorders of (mares), 475-480, 476f, 478f, 534f, 536-538
 disorders of (stallions), 480-482, 481f, 534-536, 534f
 disorders of (sheep and goats), 588
 disorders of (swine), 597-598
 drugs for, 98-99, 100-101
 ferrets and, 56
 hypertension and, 183
 marine mammals and, 650
 necropsies and, 70-75, 79-80, 81-82
 pinnipeds and, 652
 primates and, 658
 rabbits and, 629, 633-634
 reptiles and, 642-643, 645
 ruminants and, 551-554
 surgery and, 381-382, 534-538, 534f
 toxicants affecting, 141-146, 152-153
 tumors of (equine), 462-463
 ultrasonographic imaging of, 54
Reptiles, 642-647, 661
Rescue therapy, 299
Reservoir bags, 156
Resorptive lesions, 33
Respiratory syncytial virus (RSV), 488
Respiratory tract
 anesthesia and, 161
 birds and, 617
 camelids and, 575
 diagnosis of disorders of, 353-354
 disease outbreaks and, 493
 disorders of in sheep and goats, 585-586
 disorders of in swine, 595-596
 disorders of upper, 495-499, 498f, 499f
 drugs for, 97-98
 examination of (equine), 485-486
 infectious disease and, 443-446, 487-490, 489f
 marine mammals and, 650
 necropsies and, 66-69
 obstructive pulmonary disease and, 490-491, 491f
 prematurity, dysmaturity and, 486-487, 487f
 rabbits and, 631-632
 reptiles and, 642, 644
 rodents and, 636-638, 640
 ruminants and, 559-562
 surgery and, 382-393, 383f, 495-499, 498f, 499f
 toxicants affecting, 122-123
Restraint
 birds and, 612
 of camelids, 570
 of cats, 366-367, 366f

Restraint *(Continued)*
cetaceans and, 657
of dogs, 365-366, 366f
equine, 493-494, 494f
of ferrets, 625, 625f
fish and, 648
indications for, 365
marine mammals and, 650
pinnipeds and, 652
poultry and, 599
primates and, 658, 659
rabbits and, 629, 630f
reptiles and, 643
sheep, goats and, 578, 578f
verbal, 365
Restrictive cardiomyopathy, 174-176
Retained endochondral cartilaginous cores, 324
Retained incisors, 573
Retained placenta, 552, 576
Retained spectacles, 646
Retained teeth, 499
Reticulocyte count, 24
Reticuloperitonitis, 71, 556
Retinal detachment, 92
Retinal dysplasia (RD), 91
Retinas, 91-92
Retractor oculi reflex tests, 278
Retropharyngeal abscesses, 585
Revolution, 336, 337t
Rhabdomyomatosis, 640
Rhabdomyosarcomas, 301, 463
Rhabdoviruses, 267
Rheum rhaponticum, 120
Rheumatoid arthritis, 329
Rhinitis, 42, 66-67, 354-355, 595-596
Rhinopneumonitis, 471
Rhinotracheitis, 334-335t
Rhizoctonia leguminicola, 152
Rhodococcus equi, 75, 443-444, 488-489, 489f
Rhododendron toxicity, 115
Rhodojaponins, 115
Rhomboid skin disease, 656
Rhubarb toxicity, 120
Riboflavin, 291
Ribs, neoplasias of, 309
Ricin, 144
Ricinus communis, 144
Rickets, 66, 608, 659, 669
Rickettsia spp., 251, 268-269, 637
Rifampin, 104
Rinderpest, 568-569
Ringbone, 427
Ringworm (dermatophytosis), 193, 421, 564, 574, 597
RNA viruses, 61-62
Robert Jones bandages, 615
Robinia pseudoacacia, 144
Rocky Mountain spotted fever, 268-269
Rodenticides, 117, 130, 141, 147-148, 256, 417-418
Rodents, 35, 35f, 636-641
Romanowsky typing, 18-19
Roots (tooth), 31
Rosagenin, 113
Rot, 647
Rotaviruses, 56, 62, 74, 266, 267, 580-581, 595
Rouleaux formation, 25, 25f
Roundworms (ascarids)
diarrhea and, 232
equine, 473, 473t
impaction and, 502
overview of, 75, 75f
poultry and, 607
swine, 594
Rubriblasts, 28
Rubricytes, 28
Rumen acidosis, 580
Rumenitis, 71
Rumenotomy, 548
Rumex spp., 120
Ruminants
anesthesia and, 548-549
anthrax and, 567-568
cardiovascular system and, 559
Chlamydia spp. and, 664
foreign animal disease and, 568-569
gastrointestinal disorders and, 554-559, 663
hematologic disorders and, 562-563
hepatobiliary disease and, 563
husbandry of, 543-544
integumentary system disease and, 564
management of, 544-546
mastitis and, 549
musculoskeletal systems and, 549-551
Mycobacterium spp. and, 660
neurologic disorders and, 564-567
ophthalmology and, 567
production medicine skills for, 546-547
reproductive disorders and, 551-554
respiratory system disorders and, 559-562
surgery and, 547-548
urinary system disease and, 567
Rusterholtz ulcers, 550
Ryegrass staggers, 134

S

Sacroiliac joints, 314
Saddle rash, 421
Saggital crest, 305
Salicylate, 99
Salinomycin, 112
Salivary glands, 225-226
Salmon poisoning disease, 270
Salmonella spp.
bovines and, 557
ferrets and, 56
necropsies and, 73-74
overview of, 58, 234, 659
pet birds and, 622
pinnipeds and, 653
poultry and, 602
reptiles and, 644
rodents and, 637, 641
sheep, goats and, 581
swine and, 594
Salt, reptiles and, 642
Salt toxicity, 135-136, 589, 596
SAM. *See* S-Adenosylmethionine
Sambucus spp., 140-141
San Miguel sea lion virus, 653
Saprolegniasis, 666
Sarcocystis spp., 66, 450-451, 450f
Sarcoglycan, 288
Sarcoids, 423, 459, 459f, 515
Sarcomas
chondro-, 302, 321
fibro-, 300, 302, 304, 307, 321, 371
hemangio-, 183, 301, 302, 304, 321
injection-site, 301
leiomyo-, 301
lipo-, 300, 304
lymphoid, 80, 301, 606
myxo-, 301
neurofibro-, 301
osteo-, 66, 302, 321, 371
overview of, 300-302
rhabdomyo-, 301, 463
synovial cell, 301, 321
Sarcoptes scabiei, 195, 195f
Sarcoptic mange, 196, 419, 597
SARD. *See* Sudden acquired retinal degeneration
Scabies, 195
Scale, 189
Scapulas, 309-310
Scapulohumeral joints, 309-310, 531
SCC. *See* Squamous cell carcinomas
Schirmer tear test (STT), 84
Schistocytes, 24
Schnauzer comedo syndrome, 197
Sciatic nerve, 566
Scoliosis, 656
Scombrotoxin, 64, 654
Scouring rush, 140
Scours, 558-559
SCRAPED mnemonic, 219b
Scrapie, 588-589, 668
Screaming, birds and, 624
Scrotal hernias, 369
Scrotum, 345, 481
SDH. *See* Sorbitol dehydrogenase
Sea lions, 651-654
Seal pox, 653
Seals, 651-654
Sebaceous glands, 190, 199, 303

Seborrhea, 422
Second gas effect, 161
Secondary hyperparathyroidism, 218, 468
Sedatives, 157, 494, 549, 625
Sediment, urinalysis and, 3
Seed stock industry, 546
Seeds, birds and, 611
Seizures, 284-285, 639
Selamectin, 108, 110, 135, 180, 181, 195
Selenium, 137-138, 150-151, 290, 578
Semduramicin, 112
Semen, 344, 482-483
Seminal vesicles, 481
Seminomas, 81
Sendai virus, 636
Senecio spp., 63, 127
Sensitivities, diagnostic tests and, 16
Sentinel, 336, 337t
Septic arthritis, 52f, 521-522, 551
Septic arthritis-physitis, 52f
Septic carpitis, 551
Septic peritonitis, 375
Septicemia, 487, 648, 649, 657
Septicemic plague, 662
Serotonergic agonists, 98
Sertoli cell tumors, 81, 381
Sertoli cells, 81, 381, 480
Serum
 amylase, 10
 enzymes, 11-12
 glutamic oxaloacetic transaminase (SGOT), 8, 13
 insulin test, 15
 lipase, 10
 plasma vs., 11-12
 pyruvic transaminase (SGPT), 8-9, 13
 sodium, 202
Sesamoiditis, 527-528
Sesquiterpene lactones, 137
Sevoflurane, 160t, 404, 404t
Sex hormones, 194
Sexual behavior, 407-408
SGOT (serum glutamic oxaloacetic transaminase). *See* Aspartate aminotransferase
SGPT (serum glutamic-pyruvic transaminase). *See* Alanine aminotransferase
Shadowing, 53
"Shake and bake syndrome", 129
Shaker foal, 453
Shear teeth, 39, 39f
Shearing injuries, 318-319
Sheep. *See* Ovine management and husbandry
Sheep pox, 579
Sheepbur poisoning, 127
Shell diseases, 647
Shellfish toxins, 63, 64
Shigella spp., 61, 659
Shipping fever pneumonia, 561-562
Shivers, 455
Shock, 204-205
Shortened anestrus, 351
Shoulders, 309-310, 531
Sialoadenitis, 225-226
Sialoadenosis, 225-226
Sialoceles, 225-226, 245-246, 371-372
Sialodacryoadenitis virus, 637
Sick euthyroid, 209
Sick sinus syndrome, 185
Siderotic granules, 25
Silent estrus, 351
Silicate uroliths, 380, 393f, 395
Silymarin, 100
Simian T-lymphotrophic virus (STLV-1), 659
Sinus
 disorders of, 66-67, 354-356, 559-560, 585
 equine, 37
 fractures of frontal, 305
 necropsies and, 66-67
 rhythm, 185
 tumors of (equine), 461-462
Sinusitis, 66-67, 354-355, 559-560, 585
Sirenians, 649-651
SIV. *See* Swine influenza virus
Skeletal muscle, 111-117, 320-321
Skeletal systems, 65-66, 302, 309, 321-324, 616
Skin. *See also* Dermatology
 birds and, 615-616
 camelids and, 574-575
 cetaceans and, 655, 656
 diet and, 296
 disorders of, 514-517
 ferrets and, 627
 nodular disorders of, 422-423
 reptiles and, 642
 rodents and, 637
 ruminants and, 550, 563, 564
 structure and function of, 190-191
 swine and, 597
 toxicants affecting, 150-152
 tumors of, 303-304, 459-461, 459f
Skin grafts, 514-515
Skin scrapes, 192f
Skulls, 305, 461-462
Slab fractures, 530
Slaframine, 152
SLE. *See* Systemic lupus erythematosus
Slobbering disease, 152
Slug and snail bait, 129
Slump, 151
Small intestine
 bacterial overgrowth of, 236
 cetaceans and, 656
 diagnostic imaging of, 49
 diarrhea and, 231
 disorders of, 374-376, 502-506, 504f, 511-514
 equine anatomy, nutrition and, 456-457
Smoking, birds and, 611
Snake mites, 645
Snake venoms, 250
Socusate sodium, 99
Sodium, 1, 6, 290, 544. *See also* Hypernatremia; Hyponatremia
Sodium monofluoroacetate (Compound 1080), 130
Sodium monofluoroacetate toxicity, 130
Sodium nitroprusside, 188
Sodium sulfite precipitation test, 12
Sodium sulfonamide, 135
Solanum spp., 145
Solar canal, 425
Solar margin, 425-426
Soles, 525, 550
Solubility, anesthetics and, 160, 160t
Somatic pain, defined, 163
Somogyi effect, 219f, 220
Sorbitol dehydrogenase (SDH), 8
Sore mouth, 572, 579, 667
Sorghum toxicity, 140-141, 454
Sorrel toxicity, 120
Sotalol, 95-96, 186
SPAOPD. *See* Summer pasture associated obstructive pulmonary disease
Spasms, anorectal, 238
Specificity, diagnostic tests and, 16
Spectacles, reptiles and, 646
Sperm granulomas, 345
Spermatoceles, 345
Spherocytes, 25
Spinal cords, 83, 285-287
Spinal fractures, 308-309
Spinal reflexes, 278
Spironolactone, 186, 186t
Spironucleus muris, 637
Splay leg, 616
Spleens
 anatomy and function of, 257
 diagnostic imaging of, 47
 disorders of, 257-258
 ferrets and, 626
 necropsies and, 80
 tumors of (equine), 463
 ultrasonographic imaging of, 53
Splenomegaly, 80, 257-258
Splint bones, 529-530
Splinting, 614-615
Split estrus, 350
Spondylitis, 646
Spondylosis deformans, 42
Spongiform encephalopathies, 63, 268, 565, 668
Sporothrix schenckii, 23
Sporotrichosis, 422
Spumavirus, 268
Spur cells, 24, 25f
Squamous cell carcinoma (SCC) antigen, 303-304
Squamous cell carcinomas (SCC), 307, 371, 423, 460, 481, 515-516, 567

Squamous metaplasias, 343
St. John's wort, 152
St. Louis encephalitis, 471
Staggers, 134
Staggerweed, 140
Stance, neurologic evaluation and, 277
Staphylococcus aureus, 60
Stasis, gastrointestinal, 632-633
Statum basale, overview of, 190
Steatitis, 654
Stenosis
 anorectal, 238
 esophageal, 227, 372, 501
 imaging of pulmonary, 44-45
 tracheal, 356
 vestibulovaginal, 349
 vulvar, 349
Step mouth, 39
Sterile nodular panniculitis, 423
Steroid hepatopathy, 10, 76
Stifle, 316-317, 428, 523, 531-532
STLV-1. *See* Simian T-lymphotrophic virus
Stocker operations, 546
Stocks, 493
Stomach
 birds and, 617
 camelid, 571
 cetaceans and, 655
 disorders of, 229-231, 230f, 372-374
 equine anatomy, nutrition and, 456
 necropsies and, 72
 poultry and, 599-600
 rabbits and, 629
 tumors of (equine), 463
Stomatitis, 225, 644
Stomatocytes, 25, 249
Storage spleen, 80
Strangles (juvenile cellulitis), 199, 444, 471-472, 489-490
Strangulation, 503-504, 504f
Stratum corneum, 190
Stratum granulosum, 190
Stratum spinosum, 190
Strawberry warts, 550
Stray voltage, 544
Streptococcal disease, 596
Streptococcus equi equi, strangles and, 199, 444, 471-472, 489-490
Streptococcus pneumoniae, 659
Streptothrichosis, 653
Stress fractures, 519
Strictures
 anorectal, 238
 esophageal, 227, 372, 501
 imaging of pulmonary, 44-45
 tracheal, 356
 vestibulovaginal, 349
 vulvar, 349
Stringhalt, 454-455, 521
Strongyles, 472-473, 473t
Strongyloides spp., 233, 659
Struvite uroliths, 293, 380, 393f, 394
Strychnine poisoning, 128-129
STT. *See* Schirmer tear test
Styloid process, 311
Subaortic stenosis, 166t
Subinvolution of placental sites, 347
Sucking calf scours, 558-559
Sucralfate, 98
Sucrose, 126
Sudden acquired retinal degeneration (SARD), 91
Sugars, toxicity from, 130
Sulfonamides, 103
Sulfur, 589
Summer pasture associated obstructive pulmonary disease (SPAOPD), 490-491
Summer sores, 422-423, 516, 536
Summers syndrome, 151
Superficial necrolytic dermatitis, 198, 242
Supernumerary teeth, 39
Supplements, nutritional, 329
Suppurative enterocolitis, 235
Suppurative-neutrophilic-purulent inflammation, 19-20
Suprascapular nerve injury, 531
Supraventricular premature beats, 184
Surgery
 body cavities, hernias and, 369-370
 cetaceans and, 657
 gastrointestinal tract and, 371-379, 375f, 377f, 378f
 genital tract and, 381-382
 of integument, 370-371
 overview of, 368
 pinnipeds and, 654
 prostate gland and, 343
 reptiles and, 644
 respiratory tract and, 382-393, 383f
 ruminants and, 547-548
 of skeletal muscle and tendons, 320-321
 sutures and, 368-369
 testes and, 345
 urinary tract and, 379-381
 uterine, 348
Suri llamas, 570
Sutures, overview of, 368-369
Swainsona salsula, 137-138
Swainsonine, 137-138
Swallowing, disorders of, 226-228
Sweat glands, 190, 434
Sweating, 433-434
Sweeney, 455
Swine dysentery, 74, 594
Swine influenza virus (SIV), 596
Swine medicine and management, 592-598, 664
Swine pox, 597
Sympathomimetics, 187
Synchysis scintillans, 91
Syncytium-forming virus, 268
Syndactyly, 41
Synovial cell sarcomas, 301, 321
Synovial fluid, 521-522
Synovial membrane, 328
Synovitis, 519, 527, 603
Syphilis, 634
Systemic hypertension, 183-184
Systemic lupus erythematosus (SLE), 198-199, 257, 330
Systemic vascular resistance, 165
Systole, 165

T

T-2 toxin, 142
Table-egg industry, 600-601
Tachyarrhythmias, 185
Taeniasis. *See* Tapeworms
Tail bob, 617
Tannins, 120-121
Tape splints, 615
Tapeworms
 camelids and, 571-572
 diarrhea and, 233
 equine, 473, 473t, 507
 overview of, 62, 75
 rodents and, 637-639
 sheep, goats and, 582
Tarsal disease, 428
Tarsal joints, injuries to, 318-319
Tarsus, 531
Tattoo lesions, 656
Taurine, 292, 294
Taxus spp., 115-116
tCa. *See* Total calcium
T-cell lymphoma, 659
TCT. *See* Thrombin clotting time
Tear film, 84
Teeth. *See* Tooth
Teflon, 122, 617, 623
Tela submucosa, 501
Telangiectasis, 76
Telazol, 157, 405-406
Temporary indirect rectal liner, 513
Tendonitis, 520
Tendons, 55, 320-321, 520-521
Tenosynovitis, 521-522
Teratomas, 477
Terbutaline, 97
Testes
 birds and, 619, 620
 cancer of, 381
 defects of, 480, 481
 diagnostic imaging of, 50
 disorders of, 343-345, 534-535
 necropsies and, 81
 ultrasonographic imaging of, 54
Testicular feminization syndrome, 344, 476, 481

Tetanus, 442-443, 454, 470-471, 566, 590
Tetany, 7, 455, 551
Tetracyclines, 103
Tetrahydrocannabinols, 139
Tetralogy of Fallot, 45, 169
Tetrodotoxin poison, 64
TgAA. *See* Thyroglobulin autoantibodies
Theiler disease, 637
Theileria spp., 26
Theobromine, 97, 130-131, 281
Theophylline, 97, 130-131, 281
Theriogenology, 637-641
Thermal injuries, 645
Thermoregulation
 anesthesia and, 162
 heatstroke and, 206
 marine mammals and, 651
 pinnipeds and, 654
 reptiles and, 642
 rodents and, 639
Thevetia spp., 113-114
Thiacetarsamide, 108
Thiacetarsemide, 180
Thiamine, 291, 652
Thiamine deficiency, 281, 573, 589, 646, 654
Thiazide diuretics, 94, 186
Thiobarbiturates, 403
Thiopentanal, 158
Third eyelid, 84, 86
Third-space syndrome, 6
Thlaspi spp., 149
Thoracic cavity, 361-365, 362f
Thoracic wall, 46-47, 361
Thoracocentesis, 204
Thoracolumbar myelomalacia, 404
Thorax, 54-55, 464
Threadworms, 473, 607
Thrombin, 69
Thrombin clotting time (TCT), 255
Thrombocytopenia, 252-254, 257, 269, 417-418, 656
Thrombocytosis, 253
Thromboembolic meningoencephalitis, 565
Thromboembolism, 360, 363, 437f, 565
Thrombosis, 455
Thrush, 467, 467f, 524, 608
Thymic branchial cysts, 363
Thymomas, 80
Thymus, 80
Thyroglobulin autoantibodies (TgAA), 208
Thyroid
 birds and, 619
 dermatoses and, 194
 disorders of, 208-210, 432-433
 drugs for, 100
 hyperthyroidism and, 45-46, 79, 194, 209-210
 hypothyroidism and, 208-209, 282, 432-433, 619
 necropsies and, 79-80
 reptiles and, 643
 tumors of (equine), 462-463
Thyroid-releasing hormone (TRH), 208, 430
Thyroid-stimulating hormone (TSH), 208
L-Thyroxine, 100
Tibia, 318, 531
Tibial nerve, 566
Tibiotarsal joint, 523
Ticks, 108-110, 136, 269, 276, 607, 645
Tiletamine, 158-159
TLI. *See* Trypsin-like immunoreactivity
TMJ dislocations, 305-306
Toenail bleeding time test, 255
Toes, notched, 51
Togaviruses, 268
Tonsillar neoplasias, 225
Tonsillitis, 225
Tooth
 camelid, 571, 573
 cetaceans and, 655, 656
 equine, 472, 499-501
 ferrets and, 627
 pinnipeds and, 651
 primates and, 658, 659
 rabbits and, 629, 633
 rodents and, 638-641
 sheep, goats and, 579
Torsion, 510, 538, 553, 575-576, 656
Torticollis-head tilt-ataxia, 634
Total calcium (tCa), 214, 215t, 217t
Total protein, 12
Total T_3 test, 208
Total T_4 test, 208
Toxemia, 56, 563, 583, 641
Toxic epidermal necrolysis, 199
Toxicology
 birds and, 617, 618, 623
 circulatory system and, 146-150
 diarrhea and, 232
 food-borne, 63-64
 gastrointestinal tract and, 141-146
 heart, skeletal muscle and, 111-117
 Heinz body anemia and, 415-416
 kidneys and, 117-121
 liver and, 123-128
 nervous system and, 128-141
 pinnipeds and, 653-654
 red tide and, 651
 reproductive tracts and, 121-123, 152-153
 sheep, goats and, 584-585, 587
 skin and, 150-152
 slobbering disease and, 152
 USDA and, 57
Toxocara spp., 232
Toxoplasmosis, 63, 171, 275, 657, 668-669
Trachea
 birds and, 617
 cetaceans and, 657
 diagnostic imaging of, 43-44
 disorders of, 353-354, 356-357, 383, 383f
 necropsies and, 67
Tracheal rings, 642
Tracheal stenosis, 44
Tracheitis, 44
Tracheobronchitis, infectious, 264 357. *See also Bordetella* spp.
Tracheostomy, 204, 204f
Tramadol, 106
Tranquilizers, 157, 402-403, 494, 549, 630
Transcutaneous electrical nerve stimulation (TENS), 164
Transducers, 53
Transfusions, 206
Transitional cell carcinoma (TCC), 398-399
Transmissible gastroenteritis (TGE) virus, 74
Transmissible murine colonic hyperplasia, 637
Transmissible spongiform encephalopathies (TSEs), 63
Transmissible venereal tumors (TVT), 21, 304
Trauma, ocular, 465
Traumatic proptosis, 85
Traumatic reticuloperitonitis, 71, 556
Trematodes, 572, 582, 649, 656. *See also* Liver flukes
Treponematosis, 634
TRH. *See* Thyroid-releasing hormone
Triadan classification, 38, 38f
Trichinella spp., 62-63
Trichinellosis, 62-63
Trichobezoars, 633, 657
Trichodectes canis, 195
Trichomonas foetus, 233
Trichomoniasis, 552, 608
Trichophyton mentagrophytes, 640
Trichosomoides crassicauda, 638
Trichothecene mycotoxins, 142
Trichuris vupis, 233
Tricuspid valves, 45, 169-170, 413
Trifolium spp., 128, 140-141, 150, 153
Trigeminal neuritis, 283
Triglochin spp., 140-141
Triglycerides, evaluation of, 13
Tri-Heart, 336, 337t
Trilostane, 100-101, 212
Triple pelvic osteotomy, 315
Triple-drip sedation, 494
Trochlear notch, 311
Trombiculosis, 195
Truncal folliculitis and furunculosis, 421
Trypanosoma cruzi, 171
Trypsin-like immunoreactivity (TLI), 11

TSEs. *See* Transmissible spongiform encephalopathies
TSH. *See* Thyroid-stimulating hormone
Tuberculosis
avian, 622-623
bovine, 560-561
cetaceans and, 656
ferrets and, 626
overview of, 659-660
primates and, 657, 658, 659
Tubulointerstitial disease, 540
Tularemia, 272
Tulipia spp., 145
Tumor necrosis factor-α (TNF-α), 328
Tunica adventitia, 501
Tunica mucosa, 501
Tunica muscularis, 501
Turkeys. *See* Poultry
TVT. *See* Transmissible venereal tumors
Twinning, 82
Twitching, 493, 494f
Tympany, 495, 507
Typhoid, 602-603
Tyzzer disease, 74, 637, 639

U

UAP. *See* Ununited anconeal process
UCCR. *See* Urinary cortisol-to-creatinine ratio
Udders, 564. *See also* Mastitis
Ulcerative colitis, 235
Ulcerative enteritis, 604
Ulcerative keratitis, 86-87
Ulcerative lymphangitis, 422
Ulcerative pododermatitis, 631
Ulcerative pyoderma, 627
Ulcers. *See also* Equine gastric ulcer syndrome
abomasal, 580
camelids and, 573
cetaceans and, 656
defined, 190
equine, 437
gastroduodenal, 229
necropsies and, 72
pinnipeds and, 654
ruminants and, 556
sole, 550
Ulna, 311-312, 530
Ultrasonography, 53-55, 614, 629
Umbilical cord torsion, 82
Umbilical hernias, 369
Umbilical herniorrhaphy, 548
Unclassified cardiomyopathy, 176
Unconjugated (indirect) bilirubin, 9
Unidirectional valves, 156
Unilateral renal agenesis, 385
Universal systems, 156
Ununited anconeal process (UAP), 324, 325f
Upper GI series, 50
Urachus, 397, 533, 541, 541f
Urate uroliths, 380
Urea, 1, 132, 655
Ureter
birds and, 618
disorders of, 532
ectopic, 47, 78, 379-380, 396-397, 532, 541
Ureteral ectopia, 47, 78, 379-380, 396-397, 532, 541
Urethra
calculi of, 567
cancer of, 481
diagnostic imaging of, 48
disorders of, 399-400, 532-533
obstructions of, 397-398
stones and, 380
Urethral brush specimens, 342
Urethritis, 399-400
Urinalysis, 2
Urinary cortisol-to-creatinine ratio (UCCR), 210
Urinary incontinence, 395-397, 541
Urinary tract
birds and, 618-619
diagnostic imaging of, 47-48
disorders of, 532-533
disorders of in sheep and goats, 587-588
disorders of lower, 390-400, 393f, 395f, 540-541
disorders of upper, 384-390, 389f
drugs for, 102
ferrets and, 56
necropsies and, 77-79
overview of, 384
rabbits and, 629, 633-634
reptiles and, 646-647
rodents and, 637, 638, 639
ruminants and, 567
surgery and, 379-381
tumors of (equine), 463
Urinary tract infections, 389-391
Urine, 15
Urine osmolality, 1
Urine pooling, 536-537
Uroabdomen, 398
Urodeum, 617
Urolithiasis
ammonium urate, 293, 393f, 394
calcium oxalate, 293, 380, 393f, 394
calcium phosphate, 293, 393f, 394
cystine, 293, 380, 393f, 395
diet and, 293
ferrets and, 56
necropsies and, 78-79
obstructive, 541
overview of, 392-394
reptiles and, 646-647
rodents and, 641
sheep, goats and, 577, 587-588
silicate, 380, 393f, 395
Urolithiasis *(Continued)*
struvite, 293, 380, 393f, 394
surgery and, 533
urate, 380
xanthine, 393f, 395, 395f
Urology, equine, 539-541
Uroperitoneum, 532-533
Urovagina, 536-537
Ursodiol, 99
Urticaria, 423
U.S. Department of Agriculture (USDA), 56, 568
Uterine arteries, 538
Uterine prolapse, 347
Uterus
adenocarcinoma, hyperplasia of, 633
anatomy of, 348f
diagnostic imaging of, 50
disorders of, 346-348, 477-479, 478f, 537-538, 575-576
evaluation of (equine), 475
fluid of, 477-478
necropsies and, 81
prolapse of, 347
ultrasonographic imaging of, 54
Uveas, 88-89
Uveitis, 88-89, 465-466
Uveodermatologic syndrome, 199

V

Vaccinations
camelids and, 571
dairy cows and, 545
fish and, 649
overview of, 332, 333-336t, 470-472
poultry and, 599
Vacuolar hepatopathies, 241-242
Vagal nerve disease, 559
Vagina, 348-350, 476, 536-537, 553-554, 588
Vaginal edema, 350
Vaginal vestibule, 475
Vaginitis, 350
Valley Fever, 273, 273f, 665, 666
Valvular endocardiosis, 176-177
Valvular endocarditis, 70, 165, 177-178, 584
Valvular heart disease, 627
Valvular insufficiencies, 45
Valvular pulmonic stenosis, 168
Vaporizers, 155
Variant Cruetzfeldt-Jakob disease (vCJD), 63
Varicoceles, 345
Vascular dermatitis, 645
Vascular encephalopathies, 281
Vascular ring anomalies, 45, 171, 228, 372
Vasculitis, 280, 281, 417
Vasodilators, 94, 187
Velvet disease, 649

Venereal diseases, 482, 551-552
Venodilators, 188
Ventilation, 544, 600
Ventricular rhythms, 185
Ventricular septal defects (VSD), 165, 170-171, 584
Ventriculocordectomy, 498
Ventriculus, 617
Vents, birds and, 618
Verapamil, 96, 186
Veratrum californicum, 116
Verbal restraint, 494
Verminous myelitis, 451-452
Verotoxin, 58-59
Verrucous sarcoids, 515
Vertebrae, 309, 634
Very low-density lipoproteins, 13-14
Vesicles, defined, 189
Vesicular stomatitis virus (VSV), 492, 569, 579
Vestibules, 348-350
Vestibulo-ocular reflex, 93
Vetches, 137-138, 152
Viborg's triangle, 496
Vibrio spp., 61, 602
Vicia villosa, 152
Vicuña, 570-576
Villous atrophy, 235-236
Virginiamycin, 112
Viruses
 abortion and, 82
 anemia and, 250-251
 birna, 268, 605
 caliciviruses, 62, 263, 335t, 653
 diarrhea and, 234
 equine infectious anemia (EIA) and, 439
 feline immunodeficiency, 261-262, 336t
 feline leukemia, 250, 260-261
 ferrets and, 626
 fish and, 648
 food-borne infections and, 58, 61-62
 intestinal, 265-267
 necropsies and, 74-75
 pinnipeds and, 653
 pneumonia and, 44
 poultry and, 604-606
 primates and, 659
 respiratory (sheep, goats), 586
 rhinitis, sinusitis and, 355
 rodents and, 636
 swine and, 596
Visceral pain, defined, 163
Viscum album, 145-146
Vision, 92-93, 658. *See also* Eyes; Ophthalmology
Vitamin A, 291, 293, 647, 647f
Vitamin B_1, 291, 652
Vitamin B_{12}, 251
Vitamin B_{12} assay, 11
Vitamin B_2, 291
Vitamin B_3, 291, 292-293
Vitamin B_6, 293
Vitamin C, 291
Vitamin D, 291, 646, 659, 669-670
Vitamin D toxicity, 8, 117-118, 216, 433, 468
Vitamin E, 291, 609, 652, 654
Vitamin K, 255, 256, 291, 647
Vitamins, 290-291, 292-293, 458, 669-670
Vitreous gel, 91-92
Vitritis, 91
VKH syndrome. *See* Uveodermatologic syndrome
VLDL (very low-density lipoproteins), 13-14
Vocalization, birds and, 624
Vogt-Koyangi-Harada (VKH) syndrome, 199
Volatile fatty acids, 577
Volvulus, 72, 376, 377f, 503, 558, 558f
Vomitoxin, 142
von Willebrand Disease, 255-256
VSD. *See* Ventricular septal defects
VTEC. *See E. coli* 0157:H7
Vulva, 56, 348-350, 536-537
vWD. *See* von Willebrand Disease

W

Walking dandruff, 195-196
Walruses, 651-654
Warbles, 564
Warfarin, 256
Warts. *See* Digital dermatitis; Papillomatosis
Wasting diseases, 618, 622, 668
Water, 135-136, 201, 290, 589, 648
Water hemlock, 136-137
Water mold, 649
Wave mouth, 38, 39f
WBC. *See* White blood cells
Weals, defined, 189
Weaned calf scours, 559
Weanlings, 435, 623
Wean-to-estrus interval (WEI), 593
Weckenbach block, 185
WEE. *See* Western equine encephalitis
WEI. *See* Wean-to-estrus interval
West Nile virus, 268, 471, 572, 623, 647
Western equine encephalitis (WEE), 442, 471
Whales, 654-657
Wheelbarrowing, 277
Wheezing, 486
Whipworms, 75, 233, 594
White blood cells (WBC), 3, 655
White muscle disease, 584
White-fat disease. *See* Vitamin E
White-line disease, 524
Whooping cough, 659
Wild horses, 407
Williams, Vaughn, 186
Winter dysentery, 75
Wobbler syndrome, 41, 307-308
Wolf teeth, 37, 38, 499
Wood preservatives, 141-142
Wooden tongue (actinobacillosis), 554, 579
Worms, 107-108, 594-595. *See also Specific worms*
Wounds, 368, 370, 514
Wry nose, 499

X

Xanthine uroliths, 393f, 395, 395f
Xanthium spp., 127
Xenografts, 514
X-rays, 40
Xylazine, 157, 405
Xylitol toxicity, 126
D-Xylose absorption test, 11

Y

Yellow oleander, 113-114
Yersinia spp., 60, 662, 664-665. *See also* Plague
Yew toxicity, 115-116
Yohimbine, 192

Z

Zearalenone, 152-153
Zigadenus spp., 116
Zinc, 100, 197-198, 290, 574
Zinc sulfate turbidity test, 12
Zinc toxicity, 141, 147, 250, 623, 657
Zolazepam, 157
Zona fasciculata, 210
Zona glomerulosa, 210, 213
Zona reticularis, 210
Zoonoses, 57-64, 276, 445, 568-569, 579, 604, 634, 658-659. *See also* Anthrax; Leptospirosis; Salmonellosis
Zygomatic arches, 305
Zygomycetes, 234
Zygomycosis, 234

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